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Mitsuaki OSHIMA et al.
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VERIFICATION

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

I, Toshimine IDE, c/o Matsushita Electric Industrial Co., Ltd., 1006, Oaza Kadoma, Kadoma-shi, Osaka 571-8501 JAPAN, declare and say:

that, I am thoroughly conversant in both the Japanese and English languages; and

that I am presently engaged as a translator in these languages;

that the attached document represents a true English translation of the Japanese Priority Application No. 3-182236 filed July 23, 1991.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signed this 27th day of June, 2002

Toshimine IDE

07.12.92

PATENT OFFICE

JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy of the following application as filed with this office.

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[Document name] Specification

[Title of the invention] Signal transmission system

[Claims]

1. A signal transmission system for transmitting data comprising a signal input unit, a modulation unit for modulating two carriers orthogonal to each other by the input signal from the input unit and generating m signal points where $m \geqq 5$ on a signal space diagram, and a transmission unit for transmitting a modulation signal, wherein a first data stream and a second data stream of n values are fed as the input signal, the signal points are divided into n signal point groups, the signal point groups are assigned to data of the first data stream individually, and the data of the second data group are assigned to the signal points in the signal point groups and transmitted.

2. A signal transmission system comprising an input unit of reception signal, a demodulator for demodulating QAM modulation signal of signal point of P value on a signal space diagram, and an output unit, wherein the signal point is divided into n signal point groups, a first data stream

is demodulated by corresponding each signal point group to the n-value first data stream, a second data stream is demodulated by corresponding the P/n value second data stream to the individual P/n signal points in the signal point groups, and data in the first data stream and second data stream are demodulated and reproduced.

3. A signal transmission system for transmitting data comprising a signal input unit, a modulation unit for modulating plural carriers differing in phase by the input signal from the input unit and generating m signal points where $m \geqq 5$ on a signal space diagram, and a transmission unit for transmitting a modulated signal, wherein a first data stream and a second data stream of n values are fed as the input signal, the signal points are divided into n signal point groups, the signal point groups are assigned to n-value data of the first data stream individually, the data in the second data group are assigned to the signal points of the signal point groups, the transmission signal is sent by a transmitter which transmits, the signal points are divided into n signal point groups by a reception apparatus

comprising an input unit of the transmission signal, a demodulator for demodulating the QAM modulated wave of P-value signal point, and an output unit, and the first data stream of n value of each signal point group is corresponded and demodulated, and the second data stream of p/n value is corresponded to the signal point of p/n value in the signal point group and demodulated, and the data in the first data stream and second data stream are demodulated and reproduced by using the reception apparatus.

4. A signal transmission system of claim 1, wherein the video signal is separated into a high frequency band video signal and a low frequency band video signal, the low frequency band video signal is transmitted as the first data stream, and the high frequency band signal is transmitted as the second data stream.

5. A signal transmission system of claim 2, wherein the video signal is separated into a high frequency band video signal and a low frequency band video signal, the low frequency band video signal is transmitted as the first data stream, and the high frequency band signal is transmitted as

the second data stream.

6. A signal transmission system of claim 3, wherein the video signal is separated into a high frequency band video signal and a low frequency band video signal, the low frequency band video signal is transmitted as the first data stream, and the high frequency band signal is transmitted as the second data stream.

7. A signal transmission system of claim 1, wherein both first data group and second data group may be created during transmission or reception, and when the code error rate of the second data group becomes high during transmission, the transmission or reception of the second data group is stopped, so that only the first data group is transmitted.

8. A signal transmission system of claim 2, wherein the operation may be limited to transmission of first data stream alone as required, if the code error rate of the second data stream becomes high while receiving both first data stream and second data stream.

9. A signal transmission system of claim 2, wherein a carrier reproducing unit for reproducing a carrier from

reception signal is provided, and the carrier reproducing unit reproduces the carrier by multiplying the frequency of the reception signal by 16 times.

DETAILED DESCRIPTION OF THE INVENTION

Industrial Field of Utilization

The present invention relates to a signal transmission system for transmitting a digital signal by modulating two carriers orthogonal to each other.

Prior Art

Digital transmission systems are used widely in various fields recently. In particular, the advancement of satellite transmission technology is dramatic.

As a recent application, the image digital satellite transmission system comes to be noticed. The image digital satellite transmission apparatus is partly used as mobile repeating means for broadcasting stations at the present, and its application in satellite broadcasting is expected in future.

From the viewpoint of broadcasting, the public interest is important, and it is essential to keep the existing right of all viewers for a long period. Henceforth, broadcasting is demanded to present plural services in one channel. In this case, it is not permitted if one service in a same channel disturbs the other service. Compatibility of plural services is important.

On the other hand, to meet the needs of the viewers becoming more and more sophisticated, it is required to improve the broadcast services both in quality and in quantity by presenting, for example, HDTV broadcast, high quality music broadcast, information presenting broadcast and FAX broadcast. However, the assignment of broadcast channels is limited. Therefore it is required to increase the information quantity within a limited frequency range of broadcast channel.

Hence, forthcoming new transmission standards, such as digital TV broadcasting standards, are required to have extendability of information quantity to cope with the future social demands and technical progress and compatibil-

ity with existing apparatus.

The conventional transmission system such as satellite transmission is reviewed here from the viewpoint of compatibility and extendability.

At the present, HDTV broadcasting is being studied as a new broadcasting service. The satellite broadcasting system of the mainstream HDTV is the analog system represented by MUSE system. These systems are hardly compatible with the existing NTSC broadcasting. Lately is proposed a method for broadcasting in 4 to 20 channels by using one transponder, as digital satellite broadcasting method, by compressing NTSC TV signals to 6 Mbps or less and multiplexing in the TDM system by using quarternary PSK modulation. In addition, as the HDTV broadcasting system, a method of compressing HDTV signal to data quantity of about 15 Mbps, and broadcasting is also proposed.

Problems that the Invention Is to Solve

In the proposed method of employing the conventional signal transmission system, in HDTV broadcasting, transmis-

sion is effected merely by using 3 to 10 channels of NTSC. Accordingly, the NTSC channels occupied by the HDTV broadcasting cannot be received during HDTV broadcasting. The compatibility of the conventional NTSC and HDTV was not satisfactory. Besides, no consideration was given to the extendability of the information amount that may be required in the future.

The invention is to solve these problems of the prior art, and it is an object thereof to present a signal transmission system capable of realizing digital TV broadcasting, possessing compatibility of NTSC broadcasting the HDTV broadcasting, and extendability of NTSC broadcasting standard into HDTV broadcasting standard.

Means of Solving the Problems

To achieve the above object, the signal transmission system of the invention presents a transmission apparatus for transmitting data comprising a signal input unit, a modulation unit for modulating plural carriers differing in phase by the input signal from the input unit and generating

m signal m points ($m \geqq 5$) on a signal vector diagram, and a transmission unit for transmitting a modulated signal, and a reception apparatus comprising an input unit of the transmission signal, a demodulator for demodulating QAM modulated waves of signal point of one value on the vector diagram, and an output unit.

Operation of the Invention

In this constitution, a first data stream and a second data stream possessing n pieces of data are entered as input signal, and modulated waves of the QAM system of variable m values having signal points of m value on the vector diagram are prepared by the modulator of the transmission apparatus. Dividing these m signal points into n sets of signal point groups, and the signal point groups are assigned to n pieces of data of the first data stream, and the data of the second data stream are assigned to m/n signal points or sub signal point groups in the signal point groups, and transmission signals are sent out from the transmission apparatus. Depending on the case, third data may be also sent out.

Next, in the reception apparatus possessing a demodulator of p values where p>m, the transmission signal is received, and p signal points are divided into n sets of signal point groups first with respect to the p signal points on the signal space diagram, then the signals of the first data stream are demodulated and reproduced. The first data and second data are demodulated and reproduced by demodulating by corresponding the second data stream of p/n values to the p/n signal points in the corresponding signal point groups. In the receiver where p = n, n signal point groups are reproduced, and corresponding to n values each, only the first data stream is demodulated and reproduced.

In this action, when same signals are received from the transmission apparatus, the first data stream and the second data stream are demodulated in a receiving having a large antenna and multiple demodulating capability. In the receiving having a small antenna and less demodulating capability, the first data stream is received. In this way, a compatible transmission system can be built up. In this case, by assigning the first data stream to the low frequen-

cy band TV signals of low frequency band components of NTSC or HDTV, and the second data stream to the high frequency band TV signals of high frequency band components of HDTV or the like, the NTSC signal is received in the receiver having a less demodulating capability for same radio wave, while the HDTV signal is received in the receiver having a multiple demodulating capability. Thus, digital broadcasting compatible between NTSC and HDTV is realized.

PREFERRED EMBODIMENTS OF THE INVENTION

Embodiment 1

One embodiment of the present invention will be described referring to the relevant drawings.

Fig. 1 shows the entire arrangement of a signal transmission system according to the present invention. A transmitter 1 comprises an input unit 2, a divider circuit 3, a modulator 4, and a transmitter unit 5. In action, each input multiplex signal is divided by the divider circuit 3 into three groups, a first data stream D1, a second data stream D2, and a third data stream D3, which are then modu-

lated by the modulator 4 before transmitted from the transmitter unit 5. The modulated signal is sent up from an antenna 6 through an uplink 7 to a satellite 10 where it is intercepted by an uplink antenna 11 and amplified by a transponder 12 before transmitted from a downlink antenna 13 towards the ground.

The transmission signal is then sent down through three downlinks 21, 32, and 41 to a first 23, a second 33, and a third receiver 43 respectively. In the first receiver 23, the signal intercepted by an antenna 22 is fed through an input unit 24 to a demodulator 25 where its first data stream only is demodulated, while the second and third data streams are not recovered, before transmitted further from an output unit 26.

Similarly, the second receiver 33 allows the first and second data streams of the signal intercepted by an antenna 32 and fed from an input unit 34 to be demodulated by a demodulator 35 and then, summed by a summer 37 to a single data stream which is then transmitted further from an output unit 36.

The third receiver 43 allows all the first, second, and third data streams of the signal intercepted by an antenna 42 and fed from an input unit 44 to be demodulated by a demodulator 45 and then, summed by a summer 47 to a single data stream which is then transmitted further from an output unit 46.

As understood, the three discrete receivers 23, 33, and 43 have their respective demodulators of different characteristics such that their outputs demodulated from the same frequency band signal of the transmitter 1 contain data of different sizes. More particularly, three different but compatible data can simultaneously be carried on a given frequency band signal to their respective receivers. For example, each of three, existing NTSC, HDTV, and super HDTV, digital signals is divided into a low, a high, and a super high frequency band components which represent the first, the second, and the third data stream respectively. Accordingly, the three different TV signals can be transmitted on a one-channel frequency band carrier for simultaneous reproduction of a medium, a high, and a super high resolution TV

image respectively.

In service, the NTSC TV signal is intercepted by a receiver accompanied with a small antenna for demodulation of small-sized data, the HDTV signal is intercepted by a receiver accompanied with a medium antenna for demodulation of medium-sized data, and the super HDTV signal is intercepted by a receiver accompanied with a large antenna for demodulation of large-sized data. Also, as illustrated in Fig. 1, a digital NTSC TV signal containing only the first data stream for digital NTSC TV broadcasting service is fed to a digital transmitter 51 where it is received by an input unit 52 and modulated by a demodulator 54 before transmitted further from a transmitter unit 55. The demodulated signal is then sent up from an antenna 56 through an uplink 57 to the satellite 10 which in turn transmits the same through a downlink 58 to the first receiver 23 on the ground.

The first receiver 23 demodulates with its demodulator 24 the modulated digital signal supplied from the digital transmitter 51 to the original first data stream signal. Similarly, the same modulated digital signal can be inter-

cepted and demodulated by the second 33 or third receiver 43 to the first data stream or NTSC TV signal. In summary, the three discrete receivers 23, 33, and 43 all can intercept and process a digital signal of the existing TV system for reproduction.

The arrangement of the signal transmission system will be described in more detail.

Fig. 2 is a block diagram of the transmitter 1, in which an input signal is fed across the input unit 2 and divided by the divider circuit 3 into three digital signals containing a first, a second, and a third data stream respectively.

Assuming that the input signal is a video signal, its low frequency band component is assigned to the first data stream, its high frequency band component to the second data stream, and its super-high frequency band component to the third data stream. The three different frequency band signals are fed to a modulator input 61 of the modulator 4. Here, a signal point modulating/changing circuit 67 modulates or changes the positions of the signal points accord-

ing to an externally given signal. The modulator 4 is arranged for amplitude modulation on two 90° -out-of-phase carriers respectively which are then summed to a multiple QAM signal. More specifically, the signal from the modulator input 61 is fed to both a first 62 and a second AM modulator 63. Also, a carrier wave of $\cos(2\pi fct)$ produced by a carrier generator 64 is directly fed to the first AM modulator 62 and also, to a $\pi/2$ phase shifter 66 where it is 90° shifted in phase to a $\sin(2\pi fct)$ form prior to transmitted to the second AM modulator 63. The two amplitude modulated signals from the first and second AM modulators 62, 63 are summed by a summer 65 to a transmission signal which is then transferred to the transmitter unit 5 for output. This procedure is well known and will no further be explained.

The QAM signal will now be described in a common 8x8 or 16 state constellation referring to the first quadrant of a space diagram in Fig. 3. The output signal of the modulator 4 is expressed by a sum vector of two, $A\cos 2\pi fct$ and $B\cos 2\pi fct$, vectors 81, 82 which represent the two

90° -out-of-phase carriers respectively. When the distal point of a sum vector from the zero point represents a signal point, the 16 QAM signal has 16 signal points determined by a combination of four horizontal amplitude values a_1, a_2, a_3, a_4 and four vertical amplitude values b_1, b_2, b_3, b_4. The first quadrant in Fig. 3 contains four signal points 83 at C_{11}, 84 at C_{12}, 85 at C_{22}, and 86 at C_{21}.

C_{11} is a sum vector of a vector $0\text{-}a_1$ and a vector $0\text{-}b_1$ and thus, expressed as $C_{11} = a_1\cos 2\pi fct - b_1 \sin 2\pi fct = A\cos(2\pi fct + d\pi/2)$.

It is now assumed that the distance between 0 and a_1 in the orthogonal coordinates of Fig. 3 is A_1, between a_1 and a_2 is A_2, between 0 and b_1 is B_1 and between b_1 to b_2 is B_2.

As shown in Fig. 4, the 16 signal points are allocated in vector coordinate, in which each point represents a four-bit pattern thus to allow the transmission of four bit data per period or time slot.

Fig. 5 illustrates a common assignment of two-bit patterns to the 16 signal points.

When the distance between two adjacent signal points is

great, it will be identified by the receiver with much ease. Hence, it is desired to space the signal points at greater intervals. If two particular signal points are allocated near to each other, they are rarely distinguished and error rate will be increased. Therefore, it is most preferred to have the signal points spaced at equal intervals as shown in Fig. 5, in which the 16 QAM signal is defined by $A_1 = A_2/2$.

The transmitter 1 of the embodiment is arranged to divide an input digital signal into a first, a second, and a third data or bit stream. The 16 signal points or groups of signal points are divided into four groups. Then, 4 two-bit patterns of the first data stream are assigned to the four signal point groups respectively, as shown in Fig. 6. More particularly, when the two-bit pattern of the first data stream is 11, one of four signal points of the first signal point group 91 in the first quadrant is selected depending on the content of the second data stream for transmission. Similarly, when 01, one signal point of the second signal point group 92 in the second quadrant is selected and transmitted. When 00, one signal point of the third signal point

group 93 in the third quadrant is transmitted and when 10, one signal point of the fourth signal point group 94 in the fourth quadrant is transmitted. Also, 4 two-bit patterns in the second data stream of the 16 QAM signal, or e.g. 16 four-bit patterns in the second data stream of a 64-state QAM signal, are assigned to four signal points or sub signal point groups of each of the four signal point groups 91, 92, 93, 94 respectively, as shown in Fig. 7. It should be understood that the assignment is symmetrical between any two quadrants. The assignment of the signal points to the four groups 91, 92, 93, 94 is determined by priority to the two-bit data of the first data stream. As the result, two-bit data of the first data stream and two-bit data of the second data stream can be transmitted independently. Also, the first data stream will be demodulated with the use of a common 4 PSK receiver having a given antenna sensitivity. If the antenna sensitivity is higher, a modified type of the 16 QAM receiver of the present invention will intercept and demodulate both the first and second data streams with equal success.

Fig. 8 shows an example of the assignment of the first and second data streams in two-bit patterns.

When the low frequency band component of an HDTV video signal is assigned to the first data stream and the high frequency component to the second data stream, the 4 PSK receiver can produce an NTSC-level picture from the first data stream and the 16- or 64-state QAM receiver can produce an HDTV picture from a composite reproduction signal of the first and second data streams.

Since the signal points are allocated at equal intervals, there is developed in the 4 PSK receiver a threshold distance between the coordinate axes and the shaded area of the first quadrant, as shown in Fig. 9. If the threshold distance is A_{TO}, a 4 PSK signal having an amplitude of A_{TO} will successfully be intercepted. However, the amplitude has to be increased to a three times greater value or $3A_{TO}$ for transmission of a 16 QAM signal while the threshold distance A_{TO} being maintained. More particularly, the energy for transmitting the 16 QAM signal is needed nine times greater than that for sending the 4 PSK signal. Also,

when the 4 PSK signal is transmitted in a 16 QAM mode, energy waste will be high and reproduction of a carrier signal will be troublesome. Above all, the energy available for satellite transmitting is not abundant but strictly limited to minimum use. Hence, no large-energy-consuming signal transmitting system will be put into practice until more energy for satellite transmission is available. It is expected that a great number of the 4 PSK receivers are introduced into the market as digital TV broadcasting is soon in service. After introduction to the market, the 4 PSK receivers will hardly be shifted to higher sensitivity models because a signal intercepting characteristic gap between the two, old and new, models is high. Therefore, the transmission of the 4 PSK signals must not be abandoned. In this respect, a new system is desperately needed for transmitting the signal point data of a quasi 4 PSK signal in the 16 QAM mode with the use of less energy. Otherwise, the limited energy at a satellite station will degrade the entire transmission system.

The present invention resides in a multiple signal

level arrangement in which the four signal point groups 91, 92, 93, 94 are allocated at a greater distance from each other, as shown in Fig. 10, for minimizing the energy consumption required for 16 QAM modulation of quasi 4 PSK signals.

For clearing the relation between the signal receiving sensitivity and the transmitting energy, the arrangement of the digital transmitter 51 and the first receiver 23 will be described in more detail referring to Fig. 1.

Both the digital transmitter 51 and the first receiver 23 are formed of known types for data transmission or video signal transmission e.g. in TV broadcasting service. As shown in Fig. 17, the digital transmitter 51 is a 4 PSK transmitter equivalent to the multiple-bit QAM transmitter 1, shown in Fig. 2, without AM modulation capability. In operation, an input signal is fed through an input unit 52 to a modulator 54 where it is divided by a modulator input 121 to two components. The two components are then transferred to a first two-phase modulator circuit 122 for phase modulation of a base carrier and a second two-phase modula-

tor circuit 123 for phase modulation of a carrier which is 90° out of phase with the base carrier respectively. Two outputs of the first and second two-phase modulator circuits 122, 123 are then summed by a summer 65 to a composite modulated signal which is further transferred from a transmitter unit 55.

The resultant modulated signal is shown in the space diagram of Fig. 18.

It is known that the four signal points are allocated at equal distances for achieving optimum energy utilization. Fig. 18 illustrates an example where the four signal points 125, 126, 127, 128 represent 4 two-bit patterns, 11, 01, 00, and 10 respectively. It is also desired for successful data transfer from the digital transmitter 51 to the first receiver 23 that the 4 PSK signal from the digital transmitter 51 has an amplitude of not less than a given level. More specifically, when the minimum amplitude of the 4 PSK signal needed for transmission from the digital transmitter 51 to the first receiver 23 of 4 PSK mode, or the distance between 0 and a_1 in Fig. 18 is A_{TO}, the first receiver 23 can suc-

cessfully intercept any 4 PSK signal having an amplitude of more than A_{TO}.

The first receiver 23 is arranged to receive at its small-diameter antenna 22 a desired or 4 PSK signal which is transmitted from the transmitter 1 or digital transmitter 51 respectively through the transponder 12 of the satellite 10 and demodulate it with the demodulator 24. In more particular, the first receiver 23 is substantially designed for interception of a digital TV or data communications signal of 4 PSK or 2 PSK mode.

Fig. 19 is a block diagram of the first receiver 23 in which an input signal received by the antenna 22 from the satellite 12 is fed through the input unit 24 to a carrier reproducing circuit 131 where a carrier wave is demodulated and to a $\pi/2$ phase shifter 132 where a 90° phase shifted carrier wave is demodulated. Also, two 90°-out-of-phase components of the input signal are detected by a first 133 and a second phase detector circuit 134 respectively and transferred to a first 136 and a second discrimination/demodulation circuit 137 respectively. Two demodulated

components from their respective discrimination/demodulation circuits 136 and 137, which have separately been discriminated at units of time slot by means of timing signals from a timing wave extracting circuit 135, are fed to a first data stream reproducing unit 232 where they are summed to a first data stream signal which is then delivered as an output from the output unit 26.

The input signal to the first receiver 23 will now be explained in more detail referring to the vector diagram of Fig. 20. The 4 PSK signal received by the first receiver 23 from the digital transmitter 51 is expressed in an ideal form without transmission distortion and noise, using four signal points 151, 152, 153, 154 shown in Fig. 20.

In practice, the real four signal points appear in particular extended areas about the ideal signal positions 151, 152, 153, 154 respectively due to noise, amplitude distortion, and phase error developed during transmission. If one signal point is unfavorably displaced from its original position, it will hardly be distinguished from its neighbor signal point and the error rate will thus be in-

creased. As the error rate increases to a critical level, the reproduction of data becomes less accurate. For enabling the data reproduction at a maximum acceptable level of the error rate, the distance between any two signal points should be far enough to be distinguished from each other. If the distance is $2A_{R0}$, the signal point 151 of a 4 PSK signal at close to a critical error level has to stay in a first discriminating area 155 denoted by the hatching of Fig. 20 and determined by $|0-a_{R1}| \geqq A_{R0}$ and $|0-b_{R1}| \geqq A_{R0}$. This allows the signal transmission system to reproduce carrier waves and thus, demodulate a wanted signal. When the minimum radius of the antenna 22 is set to r_o, the transmission signal of more than a given level can be intercepted by any receiver of the system. The amplitude of a 4 PSK signal of the digital transmitter 51 shown in Fig. 18 is minimum at A_{T0} and thus, the minimum amplitude A_{R0} of a 4 PSK signal to be received by the first receiver 23 is determined equal to A_{T0}. As the result, the first receiver 23 can intercept and demodulate the 4 PSK signal from the digital transmitter 51 at the maximum acceptable level of

the error rate when the radius of the antenna 22 is more than r_0. If the transmission signal is of modified 16- or 64-state QAM mode, the first receiver 23 may find difficult to reproduce its carrier wave. For compensation, the signal points are increased to eight which are allocated at angles of $(\pi/4+n\pi/2)$ as shown in Fig. 25-a and its carrier wave will be reproduced by a 16x multiplication technique. Also, if the signal points are assigned to 16 locations at angles of $n\pi/8$ as shown in Fig. 25-b, the carrier of a quasi 4 PSK mode 16 QAM modulated signal can be reproduced with the carrier reproducing circuit 131 which is modified for performing 16x frequency multiplication. At the time, the signal points in the transmitter 1 should be arranged to satisfy $A_1/(A_1+A_2) = \tan(\pi/8)$.

The 16 PSK signal of the transmitter 1 will now be explained referring to the vector diagram of Fig. 9. When the horizontal vector distance A_1 of the signal point 83 is greater than A_{T0} of the minimum amplitude of the 4 PSK signal of the digital transmitter 51, the four signal points 83, 84, 85, 86 in the first quadrant of Fig. 9 stay in the

shaded or first 4 PSK signal receivable area 87. When received by the first receiver 23, the four points of the signal appear in the first discriminating area of the vector field shown in Fig. 20. Hence, any of the signal points 83, 84, 85, 86 of Fig. 9 can be translated into the signal level 151 of Fig. 20 by the first receiver 23 so that the two-bit pattern of 11 is assigned to a corresponding time slot. The two-bit pattern of 11 is identical to 11 of the first signal point group 91 or first data stream of a signal from the transmitter 1. Equally, the first data stream will be reproduced at the second, third, or fourth quadrant. As the result, the first receiver 23 reproduces two-bit data of the first data stream out of the plurality of data streams in a 16-, 32-, or 64-state QAM signal transmitted from the transmitter 1. The second and third data streams are contained in four segments of the signal point group 91 and thus, will not affect on the demodulation of the first data stream. They may however affect the reproduction of a carrier wave and an adjustment, described later, will be needed.

If the transponder of a satellite supplies an abundance

of energy, the foregoing technique of 16 to 64-state QAM mode transmission will be feasible. However, the transponder of the satellite in any existing satellite transmission system is strictly limited in the power supply due to its compact size and the capability of solar batteries. If the transponder or satellite is increased in size thus weight, its launching cost will soar. This disadvantage will rarely be eliminated by traditional techniques unless the cost of launching a satellite rocket is reduced to a considerable level. In the existing system, a common communications satellite provides as low as 20W of power supply and a common broadcast satellite offers 100W to 200W at best. For transmission of such a 4 PSK signal in the symmetrical 16-state QAM mode as shown in Fig. 9, the minimum signal point distance is needed $3A_{T0}$ as the 16 QAM amplitude is expressed by $2A_1 = A_2$. Thus, the energy needed for the purpose is nine times greater than that for transmission of a common 4 PSK signal, in order to maintain compatibility. Also, any conventional satellite transponder can hardly provide a power for enabling such a small antenna of the 4 PSK first

receiver to intercept a transmitted signal therefrom. For example, in the existing 40W system, 360W is needed for appropriate signal transmission and will be unrealistic in the respect of cost.

It would be understood that the symmetrical signal state QAM technique is most effective when the receivers equipped with the same sized antennas are employed corresponding to a given transmitting power. Another novel technique will however be preferred for use with the receivers equipped with different sized antennas.

In more detail, while the 4 PSK signal can be intercepted by a common low cost receiver system having a small antenna, the 16 QAM signal is intended to be received by a high cost, high quality, multiple-bit modulating receiver system with a medium or large sized antenna which is designed for providing highly valuable services, e.g. HDTV entertainments, to a particular person who invests more money. This allows both 4 PSK and 16 QAM signals, if desired, with a 64 DMA, to be transmitted simultaneously with the help of a small increase in the transmitting power.

For example, the transmitting power can be maintained low when the signal points are allocated at $A_1 = A_2$ as shown in Fig. 10. The amplitude A(4) for transmission of 4 PSK data is expressed by a vector 96 equivalent to a square root of $2A_1^2$. The amplitude A(16) of the entire signal is expressed by a vector 96 equivalent to a square root of $(A_1+A_2)^2 + (B_1+B_2)^2$. Then,

$$|A(4)|^2 = A_1^2+B_1^2 = A_{TO}^2+A_{TO}^2 = 2A_{TO}^2$$

$$|A(16)|^2 = (A_1+A_2)^2+(B_1+B_2)^2 = 4A_{TO}^2+4A_{TO}^2 = 28A_{TO}^2$$

$$|A(16)| / |A(4)| = 2$$

Accordingly, the 16 QAM signal can be transmitted at a two times greater amplitude and a four times greater transmitting energy than those needed for the 4 PSK signal. A modified 16 QAM signal according to the present invention will not be demodulated by a common receiver designed for symmetrical, equally distanced signal point QAM. However, it can be demodulated with the second receiver 33 when two thresholds A_1 and A_2 are predetermined to appropriate values. At Fig. 10, the minimum distance between two signal points in the first segment of the signal point group 91 is

A_1 and $A_2/2A_1$ is established as compared with the distance $2A_1$ of 4 PSK. Then, as $A_1 = A_2$, the distance becomes 1/2. This explains that the signal receiving sensitivity has to be two times greater for the same error rate and four times greater for the same signal level. For having a four times greater value of sensitivity, the radius r_2 of the antenna 32 of the second receiver 33 has to be two times greater than the radius r_1 of the antenna 22 of the first receiver 23 thus satisfying $r_2 = 2r_1$. For example, the antenna 32 of the second receiver 33 is 60 cm in diameter when the antenna 22 of the first receiver 23 is 30 cm. In this manner, the second data stream representing the high frequency component of an HDTV signal will be carried on a single channel and demodulated successfully. As the second receiver 33 intercepts the second data stream or a higher data signal, its owner can enjoy a return of his higher investment. Hence, the second receiver 33 of a higher price may be accepted. As the minimum energy for transmission of 4 PSK data is predetermined, the ratio n_{16} of modified 16 APSK transmitting energy to 4 PSK transmitting energy will be calculated

to the antenna radius r_2 of the second receiver 33 using a ratio between A_1 and A_2 shown in Fig. 10.

In particular, n_{16} is expressed by $((A_1+A_2)/A_1)^2$ which is the minimum energy for transmission of 4 PSK data. As the signal point distance suited for modified 16 QAM interception is A_2, the signal point distance for 4 PSK interception is $2A_1$, and the signal point distance ratio is $A_2/2A_1$, the antenna radius r_2 is determined as shown in Fig. 11, in which the curve 101 represents the relation between the transmitting energy ratio n_{16} and the radius r_2 of the antenna 22 of the second receiver 23.

Also, the point 102 indicates transmission of common 16 QAM at the equal distance signal state mode where the transmitting energy is nine times greater and thus will no more be practical. As apparent from the graph of Fig. 11, the antenna radius r_2 of the second receiver 23 cannot be reduced further even if n_{16} is increased more than 5 times.

The transmitting energy at the satellite is limited to a small value and thus, n_{16} preferably stays not more than 5 times the value, as denoted by the hatch of Fig. 11. The

point 104 within the hatching area 103 indicates, for example, that the antenna radius r_2 of a two times greater value is matched with a 4x value of the transmitting energy. Also, the point 105 represents that the transmission energy should be doubled when r_2 is about 5x greater. Those values are all within a feasible range.

The value of n_{16} not greater than 5x value is expressed using A_1 and A_2 as:

$$n_{16} = ((A_1+A_2)/A_1)^2 \leqq 5$$

Hence, $A_2 \leqq 1.23A_1$.

If the distance between any two signal point group segments shown in Fig. 10 is 2A(4) and the maximum amplitude is 2A(16), A(4) and A(16)-A(4) are proportional to A_1 and A_2 respectively. Hence, $(A(16))^2 \leqq 5\ (A(14))^2$ is established.

The action of a modified 64 ASPK transmission will be described as the third receiver 43 can perform 64-state QAM demodulation.

Fig. 12 is a vector diagram in which each signal point group segment contains 16 signal points as compared with 4 signal points of Fig. 10. The first signal point group

segment 91 in Fig. 12 has a 4x4 matrix of 16 signal points allocated at equal intervals including the point 170. For providing compatibility with 4 PSK, $A_1 \geqq A_{T0}$ has to be satisfied. If the radius of the antenna 42 of the third receiver 43 is r_3 and the transmitting energy is n_{64}, the equation is expressed as:

$$r_3{}^2 = \{6^2/(n-1)\}r_1{}^2$$

This relation between r_3 and n of a 64 QAM signal is also shown in the graphic representation of Fig. 13.

It is understood that the signal point assignment shown in Fig. 12 allows the second receiver 33 to demodulate only two-bit patterns of 4 PSK data. Hence, it is desired for having compatibility between the first, second, and third receivers that second receiver 33 is arranged capable of demodulating a modified 16 QAM form from the 64 QAM modulated signal.

The compatibility between the three discrete receivers can be implemented by three-level grouping of signal points, as illustrated in Fig. 14. The description will be made referring to the first quadrant in which the first signal

point group segment 91 represents the two-bit pattern 11 of the first data stream.

In particular, a first sub segment 181 in the first signal point group segment 91 is assigned the two-bit pattern 11 of the second data stream. Equally, a second 182, a third 183, and a fourth sub segment 184 are assigned 01, 00, and 10 of the same respectively. This assignment is identical to that shown in Fig. 7.

The signal point allocation of the third data stream will now be explained referring to the vector diagram of Fig. 15 which shows the first quadrant. As shown, the four signal points 201, 205, 209, 213 represent the two-bit pattern of 11, the signal points 202, 206, 210, 214 represent 01, the signal points 203, 207, 211, 215 represent 00, and the signal points 204, 208, 212, 216 represent 10. Accordingly, the two-bit patterns of the third data stream can be transmitted separately of the first and second data streams. In other words, two-bit data of the three different signal levels can be transmitted respectively.

As understood, the present invention permits not only

transmission of six-bit data but also interception of three, two-bit, four-bit, and six-bit, different bit length data with their respective receivers while the signal compatibility remains between three levels.

The signal point allocation for providing compatibility between the three levels will be described.

As shown in Fig. 15 $A_1 \geqq A_{T0}$ is essential for allowing the first receiver 23 to receive the first data stream.

It is needed to space any two signal points from each other by such a distance that the sub segment signal points, e.g. 182, 183, 184, of the second data stream shown in Fig. 15 can be distinguished from the signal point 91 shown in Fig. 10.

Fig. 15 shows that they are spaced by $2/3A_2$. In this case, the distance between the two signal points 201 and 202 in the first sub segment 181 is $A_2/6$. The transmitting energy needed for signal interception with the third receiver 43 is now calculated. If the radius of the antenna 32 is r_3 and the needed transmitting energy is n_{64} times the 4 PSK transmitting energy, the equation is expressed as:

$$r_3^2 = (12r_1)^2/(n-1)$$

This relation is also denoted by the curve 211 in Fig. 16. For example, if the transmitting energy is 6 or 9 times greater than that for 4 PSK transmission at the point 223 or 222, the antenna 32 having a radius of 8x or 6x value respectively can intercept the first, second, and third data streams for demodulation. As the signal point distance of the second data stream is close to $2/3A_2$, the relation between r_1 and r_2 is expressed by:

$$r_2^2 = (3r_1)^2/(n-1)$$

Therefore, the antenna 32 of the second receiver 33 has to be a bit increased in radius as denoted by the curve 223.

As understood, while the first and second data streams are transmitted through a traditional satellite which provides a small signal transmitting energy, the third data stream can also be transmitted through a future satellite which provides a greater signal transmitting energy without interrupting the action of the first and second receivers 23, 33 or with no need of modification of the same and thus, both the compatibility and the advancement will highly be

ensured.

The signal receiving action of the second receiver 33 will first be described. As compared with the first receiver 23 arranged for interception with a smaller radius r_1 antenna and demodulation of the 4 PSK modulated signal of the digital transmitter 51 or the first data stream of the signal of the transmitter 1, the second receiver 33 is adapted for perfectly demodulating the 16 signal state two-bit data, shown in Fig. 10, or second data stream of the 16 QAM signal from the transmitter 1. In total, four-bit data including also the first data stream can be demodulated. The ratio between A_1 and A_2 is however different in the two transmitters. The two different data are loaded to a demodulation controller 231 of the second receiver 33, shown in Fig. 21, which in turn supplies their respective threshold values to the demodulating circuit for AM demodulation.

The block diagram of the second receiver 33 in Fig. 21 is similar in basic construction to that of the first receiver 23 shown in Fig. 19. The difference is that the radius r_2 of the antenna 32 is greater than r_1 of the anten-

na 22. This allows the second receiver 33 to identify a signal component involving a smaller signal point distance. The demodulator 35 of the second receiver 33 also contains a first 232 and a second data stream reproducing unit 233 in addition to the demodulation controller 231. There is provided a first discrimination/reproduction circuit 136 for AM demodulation of modified 16 QAM signals. As understood, each carrier is a four-bit signal having two, positive and negative, threshold values about the zero level. As apparent from the vector diagram of Fig. 22, the threshold values are varied depending on the transmitting energy of a transmitter since the transmitting signal of the embodiment is a modified 16 QAM signal. When the reference threshold is TH_{16}, it is determined by, as shown in Fig. 22:

$$TH_{16} = (A_1+A_2/2) / (A_1+A_2)$$

The various data for demodulation including A_1 and A_2 or TH_{16}, and the value m for multiple-bit modulation are also transmitted from the transmitter 1 as carried in the first data stream. The demodulation controller 231 may be arranged for recovering such demodulation data through

statistic process of the received signal.

If the demodulation data is lost, the demodulation of the second data stream will hardly be executed. This will be explained referring to a flow chart shown in Fig. 24.

Even if the demodulation data is not available, demodulation of the 4 PSK at Step 313 and of the first data stream at Step 301 can be implemented. At Step 302, the demodulation data retrieved by the first data stream reproducing unit 232 is transferred to the demodulation controller 231. If m is 4 or 2 at Step 303, the demodulation controller 231 triggers demodulation of 4 PSK or 2 PSK at Step 313. If not, the procedure moves to Step 310. At Step 305, two threshold values TH_8 and TH_{16} are calculated. The threshold value TH_{16} for AM demodulation is fed at Step 306 from the demodulation controller 231 to both the first 136 and the second discrimination/reproduction circuit 137. Hence, demodulation of the modified 16 QAM signal and reproduction of the second data stream can be carried out at Steps 307 and 315 respectively. At Step 308, the error rate is examined and if high, the procedure returns to Step 313 for

repeating the 4 PSK demodulation.

As shown in Fig. 22, the signal points 85, 83 are aligned on a line at an angle of $\cos(\omega t + n\pi/2)$ while 84 and 86 are off the line. Hence, the feedback of a second data stream transmitting carrier wave data from the second data stream reproducing unit 233 to a carrier reproducing circuit 131 is carried out so that no carrier needs to be extracted at the timing of the signal points 84 and 86.

The transmitter 1 is arranged to transmit carrier timing signals at intervals of a given time with the first data stream for the purpose of compensation for no demodulation of the second data stream. The carrier timing signal enables to identify the signal points 83 and 85 of the first data stream regardless of demodulation of the second data stream. Hence, the reproduction of carrier wave can be triggered by the transmitting carrier data to the carrier reproducing circuit 131.

It is then examined at Step 304 of the flow chart of Fig. 24 whether m is 16 or not upon receipt of such a modified 64 QAM signal as shown in Fig. 23. At Step 310, it is

also examined whether m is more than 64 or not. If it is determined at Step 311 that the received signal has no equal distance signal point constellation, the procedure goes to Step 312. The signal point distance TH_{64} of the modified 64 QAM signal is calculated from:

$$TH_{64} = (A_1+A_2/2) / (A_1+A_2)$$

This calculation is equivalent to that of TH_{16} but its resultant distance between signal points is smaller.

If the signal point distance in the first sub segment 181 is A_3, the distance between the first 181 and the second sub segment 182 is expressed by (A_2-2A_3). Then, the average distance is $(A_2-2A_3)/(A_1+A_2)$ which is designated as d_{64}. When d_{64} is smaller than T_2 which represents the signal point discrimination capability of the second receiver 33, any two signal points in the segment will hardly be distinguished from each other. This judgement is executed at Step 313. If d_{64} is out of a permissive range, the procedure moves back to Step 313 for 4 PSK mode demodulation. If d_{64} is within the range, the procedure advances to Step 305 for allowing the demodulation of 16 QAM at Step 307. If it is

determined at Step 308 that the error rate is too high, the procedure goes back to Step 313 for 4 PSK mode demodulation.

When the transmitter 1 supplies a modified 8 QAM signal such as shown in Fig. 25-a in which all the signal points are at angles of $\cos(2\pi f + n \cdot \pi/4)$, the carrier waves of the signal are lengthened to the same phase and will thus be reproduced with much ease. At the time, two-bit data of the first data stream are demodulated with the 4-PSK receiver while one-bit data of the second data stream is demodulated with the second receiver 33 and the total of three-bit data can be reproduced.

The third receiver 43 will be described in more detail. Fig. 26 shows a block diagram of the third receiver 43 similar to that of the second receiver 33 in Fig. 21. The difference is that a third data stream reproducing unit 234 is added and also, the discrimination/reproduction circuit has a capability of identifying eight-bit data. The antenna 42 of the third receiver 43 has a radius r_3 greater than r_2 thus allowing smaller distance state signals, e.g. 32- or 64-state QAM signals, to be demodulated. For demodulation

of the 64 QAM signal, the first discrimination/reproduction circuit 136 has to identify 8 digit levels of the detected signal in which seven different threshold levels are involved. As one of the threshold values is zero, three are contained in the first quadrant.

Fig. 27 shows a space diagram of the signal in which the first quadrant contains three different threshold values.

As shown in Fig. 27, when the three normalized threshold values are $TH1_{64}$, $TH2_{64}$, and $TH3_{64}$, they are expressed by:

$$TH1_{64} = (A_1+A_3/2) / (A_1+A_2)$$

$$TH2_{64} = (A_1+A_2/2) / (A_1+A_2) \text{ and}$$

$$TH3_{64} = (A_1+A_2-A_3/2) / (A_1+A_2).$$

Through AM demodulation of a phase detected signal using the three threshold values, the third data stream can be reproduced like the first and second data streams explained with Fig. 21. The third data stream contains e.g. four signal points 201, 202, 203, 204 at the first sub segment 181 shown in Fig. 23 which represent 4 values of

two-bit pattern. Hence, six digits or modified 64 QAM signals can be demodulated.

The demodulation controller 231 detects the values m, A_1, A_2, and A_3 from the demodulation data contained in the first data stream demodulated at the first data stream reproducing unit 232 and calculates the three threshold values $TH1_{64}$, $TH2_{64}$, and $TH3_{64}$ which are then fed to the first 136 and the second discrimination/reproduction circuit 137 so that the modified 64 QAM signal is demodulated with certainty. Also, if the demodulation data have been scrambled, the modified 64 QAM signal can be demodulated only with a specific or subscriber receiver. Fig. 28 is a flow chart showing the action of the demodulation controller 231 for modified 64 QAM signals. The difference from the flow chart for demodulation of 16 QAM shown in Fig. 24 will be explained. The procedure moves from Step 304 to Step 320 where it is examined whether m=32 or not. If m=32, demodulation of 32 QAM signals is executed at Step 322. If not, the procedure moves to Step 321 where it is examined whether m=64 or not. If yes, A_3 is examined at Step 323. If A_3 is

smaller than a predetermined value, the procedure moves to Step 305 and the same sequence as of Fig. 24 is implemented. If it is judged at Step 323 that A_3 is not smaller than the predetermined value, the procedure goes to Step 324 where the threshold values are calculated. At Step 325, the calculated threshold values are fed to the first and second discrimination/reproduction circuits and at Step 326, the demodulation of the modified 64 QAM signal is carried out. Then, the first, second, and third data streams are reproduced at Step 327. At Step 328, the error rate is examined. If the error rate is high, the procedure moves to Step 305 where the 16 QAM demodulation is repeated and if low, the demodulation of the 64 QAM is continued.

The action of carrier wave reproduction needed for execution of a satisfactory demodulating procedure will now be described. The scope of the present invention includes reproduction of the first data stream of a modified 16 or 64 QAM signal with the use of a 4 PSK receiver. However, a common 4 PSK receiver rarely reconstructs carrier waves, thus failing to perform a correct demodulation. For compen-

sation, some arrangement are necessary at both the transmitter and receiver sides.

Two techniques for the compensation are provided according to the present invention. A first technique relates to transmission of signal points aligned at angles of $(2n-1)\pi/4$ at intervals of a given time. A second technique offers transmission of signal points arranged at intervals of an angle of $n\pi/8$.

According to the first technique, the eight signal points including 83 and 85 are aligned at angles of $\pi/4$, $3\pi/4$, $5\pi/4$, and $7\pi/4$, as shown in Fig. 38. In action, at least one of the eight signal points is transmitted during sync time slot periods 452, 453, 454, 455 arranged at equal intervals of a time in a time slot gap 451 shown in the time chart of Fig. 38. Any desired signal points are transmitted during the other time slots. The transmitter 1 is also arranged to assign a data for the time slot interval to the sync timing data region 499 of a sync data block, as shown in Fig. 41.

The content of a transmitting signal will be explained

in more detail referring to Fig. 41. The time slot group 451 containing the sync time slots 452, 453, 454, 455 represents a unit data stream or block 491 carrying a data of Dn.

The sync time slots in the signal are arranged at equal intervals of a given time determined by the time slot interval or sync timing data. Hence, when the arrangement of the sync time slots is detected, reproduction of carrier waves will be executed slot by slot through extracting the sync timing data from their respective time slots.

Such a sync timing data S is contained in a sync block 493 accompanied at the front end of a data frame 492, which is consisted of a number of the sync time slots denoted by the hatching in Fig. 41. Accordingly, the data to be extracted for carrier wave reproduction are increased, thus allowing the 4 PSK receiver to reproduce desired carrier waves at higher accuracy and efficiency.

The sync block 493 comprises sync data regions 496, 497, 498, --- containing sync data S1, S2, S3, --- respectively which include unique words and demodulation data. The phase sync signal assignment region 499 is accompanied

at the end of the sync block 493, which holds a data of I_T including information about interval arrangement and assignment of the sync time slots.

The signal point data in the phase sync time slot has a particular phase and can thus be reproduced by the 4 PSK receiver. Accordingly, I_T in the phase sync signal assignment region 499 can be retrieved without error thus ensuring the reproduction of carrier waves at accuracy.

As shown in Fig. 41, the sync block 493 is followed by a demodulation data block 501 which contains demodulation data about threshold voltages needed for demodulation of the modified multiple-bit QAM signal. This data is essential for demodulation of the multiple-bit QAM signal and may preferably be contained in a region 502 which is a part of the sync block 493 for ease of retrieval.

Fig. 42 shows the assignment of signal data for transmission of burst form signals through a TDMA method.

The assignment is distinguished from that of Fig. 41 by the fact that a guard period 521 is inserted between any two adjacent Dn data blocks 491, 491 for interruption of the

signal transmission. Also, each data block 491 is accompanied at front end a sync region 522 thus forming a data block 492. During the sinc region 522, the signal points at a phase of $(2n-1)\pi/4$ are only transmitted. Accordingly, the carrier wave reproduction will be feasible with the 4 PSK receiver. More specifically, the sync signal and carrier waves can be reproduced through the TDMA method.

The carrier wave reproduction of the first receiver 23 shown in Fig. 19 will be explained in more detail referring to Figs. 43 and 44. As shown in Fig. 43, an input signal is fed through the input unit 24 to a sync detector circuit 541 where it is sync detected. A demodulated signal from the sync detector 541 is transferred to an output circuit 542 for reproduction of the first data stream. A data of the phase sync signal assignment data region 499 (shown in Fig. 41) is retrieved with an extracting timing controller circuit 543 so that the timing of sync signals of $(2n-1)\pi/4$ data can be acknowledged and transferred as a phase sync control pulse 561 shown in Fig. 44 to a carrier reproduction controlling circuit 544. Also, the demodulated signal of

the sync detector circuit 541 is fed to a frequency multiplier circuit 545 where it is 4x multiplied prior to transmitted to the carrier reproduction controlling circuit 544. The resultant signal denoted by 562 in Fig. 44 contains a true phase data 563 and other data. As illustrated in a time chart 564 of Fig. 44, the phase sync time slots 452 carrying the $(2n-1)\pi/4$ data are also contained at equal intervals. At the carrier reproducing controlling circuit 544, the signal 562 is sampled by the phase sync control pulse 561 to produce a phase sample signal 565 which is then converted through sample-hold action to a phase signal 566. The phase signal 566 of the carrier reproduction controlling circuit 544 is fed across a loop filter 546 to a VCO 547 where its relevant carrier wave is reproduced. The reproduced carrier is then sent to the sync detector circuit 541. In this manner, the signal point data of the $(2n-1)\pi/4$ phase denoted by the shaded areas in Fig. 39 is recovered and utilized so that a correct carrier wave can be reproduced by 4x or 16x frequency multiplication. Although a plurality of phases are reproduced at the time, the absolute

phase of the carrier can successfully be identified with the use of a unique word assigned to the sync region 496 shown in Fig. 41.

For transmission of a modified 64 QAM signal such as shown in Fig. 40, signal points in the phase sync areas 471 at the $(2n-1)\pi/4$ phase denoted by the hatching are assigned to the sync time slots 452, 452b, etc. Its carrier can be reproduced hardly with a common 4 PSK receiver but successfully with the first receiver 23 of 4 PSK mode provided with the carrier reproducing circuit of the embodiment.

The foregoing carrier reproducing circuit is of COSTAS type. A carrier reproducing circuit of reverse modulation type will now be explained according to the embodiment.

Fig. 45 shows a reverse modulation type carrier reproducing circuit according to the present invention, in which a received signal is fed from the input unit 24 to a sync detector circuit 541 for producing a demodulated signal. Also, the input signal is delayed by a first delay circuit 591 to a delay signal. The delay signal is then transferred to a quadrature phase modulator circuit 592 where it is

reverse demodulated by the demodulated signal from the sync detector circuit 541 to a carrier signal. The carrier signal is fed through a carrier reproduction controller circuit 544 to a phase comparator 593. A carrier wave produced by a VCO 547 is delayed by a second delay circuit 594 to a delay signal which is also fed to the phase comparator 593. At the phase comparator 594, the reverse demodulated carrier signal is compared in phase with the delay signal thus producing a phase difference signal. The phase difference signal is sent through a loop filter 546 to the VCO 547 which in turn produces a carrier wave arranged in phase with the received carrier wave. In the same manner as of the COSTAS carrier reproducing circuit shown in Fig. 43, an extracting timing controller circuit 543 performs sampling of signal points contained in the hatching areas of Fig. 39. Accordingly, the carrier wave of a 16 or 64 QAM signal can be reproduced with the 4 PSK demodulator of the first receiver 23.

The reproduction of a carrier wave by 16x frequency multiplication will be explained. The transmitter 1 shown

in Fig. 1 is arranged to modulate and transmit a modified 16 QAM signal with assignment of its signal points at $n\pi/8$ phase as shown in Fig. 46. At the first receiver 23 shown in Fig. 19, the carrier wave can be reproduced with its COSTAS carrier reproduction controller circuit containing a 16x multiplier circuit 661 shown in Fig. 48. The signal points at each $n\pi/8$ phase shown in Fig. 46 are processed at the first quadrant by the action of the 16x multiplier circuit 661, whereby the carrier will be reproduced by the combination of a loop filter 546 and a VCO 541. Also, the absolute phase may be determined from 16 different phases by assigning a unique word to the sync region.

The arrangement of the 16x multiplier circuit will be explained referring to Fig. 48. A sum signal and a difference signal are produced from the demodulated signal by an adder circuit 662 and a subtracter circuit 663 respectively and then, multiplied each other by a multiplier 664 to a cos 2θ signal. Also, a multiplier 665 produces a sin 2θ signal. The two signals are then multiplied by a multiplier 666 to a sin 4θ signal.

Similarly, a sin 8 θ signal is produced from the two, sin 2 θ and cos 2 θ , signals by the combination of an adder circuit 667, a subtracter circuit 668, and a multiplier 670. Furthermore, a sin 16 θ signal is produced by the combination of an adder circuit 671, a subtracter circuit 672, and a multiplier 673. Then, the 16x multiplication is completed.

Through the foregoing 16x multiplication, the carrier wave of all the signal points of the modified 16 QAM signal shown in Fig. 46 will successfully be reproduced without extracting particular signal points.

However, reproduction of the carrier wave of the modified 64 QAM signal shown in Fig. 47 can involve an increase in the error rate due to dislocation of some signal points from the sync areas 471.

Two techniques are known for compensation for the consequences. One is inhibiting transmission of the signal points dislocated from the sync areas. This causes the total amount of transmitted data to be reduced but allows the arrangement to be facilitated. The other is providing

the sync time slots as described in Fig. 38. In more particular, the signal points in the $n\pi/8$ sync phase areas, e.g. 471 and 471a, are transmitted during the period of the corresponding sync time slots in the time slot group 451. This triggers an accurate synchronizing action during the period thus minimizing phase error.

As now understood, the 16x multiplication allows the simple 4 PSK receiver to reproduce the carrier wave of a modified 16 or 64 QAM signal. Also, the insertion of the sync time slots causes the phasic accuracy to be increased during the reproduction of carrier waves from a modified 64 QAM signal.

As set forth above, the signal transmission system of the present invention is capable of transmitting a plurality of data on a single carrier wave simultaneously in the multiple signal level arrangement.

More specifically, three different level receivers which have discrete characteristics of signal intercepting sensitivity and demodulating capability are provided in relation to one single transmitter so that any one of them

can be selected depending on a wanted data size to be demodulated which is proportional to the price. When the first receiver of low resolution quality and low price is acquired together with a small antenna, its owner can intercept and reproduce the first data stream of a transmission signal. When the second receiver of medium resolution quality and medium price is acquired together with a medium antenna, its owner can intercept and reproduce both the first and second data streams of the signal. When the third receiver of high resolution quality and high price is acquired with a large antenna, its owner can intercept and reproduce all the first, second, and third data streams of the signal.

If the first receiver is a home-use digital satellite broadcast receiver of low price, it will overwhelmingly be welcome by a majority of viewers. The second receiver accompanied with the medium antenna costs more and will be accepted by not common viewers but particular people who wants to enjoy HDTV services. The third receiver accompanied with the large antenna at least before the satellite output is increased, is not appropriated for home use and

will possibly be used in relevant industries. For example, the third data stream carrying super HDTV signals is transmitted via a satellite to subscriber cinemas which can thus play video tapes rather than traditional movie films and run movie business at lower cost.

When the present invention is applied to a TV signal transmission service, three different quality pictures are carried on one single channel wave and will offer compatibility with each other. Although the first embodiment refers to a 4 PSK, a modified 8 QAM, a modified 16 QAM, and a modified 64 QAM signal, other signals will also be employed with equal success including a 32 QAM, a 256 QAM, an 8 PSK, a 16 PSK, a 32 PSK signal. It would be understood that the present invention is not limited to a satellite transmission system and will be applied to a terrestrial communications system or a cable transmission system.

Embodiment 2

A second embodiment of the present invention is featured in which the physical multi-level arrangement of the first embodiment is divided into small sub levels through

e.g. discrimination in error correction capability, thus forming a logic multi-level construction. In the first embodiment, each multi-level channel has different levels in the electric signal amplitude or physical demodulating capability. The second embodiment offers different levels in the logic reproduction capability such as error correction. For example, the data D_1 in a multi-level channel is divided into two, D_{1-1}, and D_{1-2}, components and D_{1-1} is more increased in the error correction capability than D_{1-2} for discrimination. Accordingly, as the error detection and correction capability is different between D_{1-1} and D_{1-2} at demodulation, D_{1-1} can successfully be reproduced within a given error rate when the C/N level of an original transmitting signal is as low as disenabling the reproduction of D_{1-2}. This will be implemented using the logic multi-level arrangement.

More specifically, the logic multi-level arrangement is consisted of dividing data of a modulated multi-level channel and discriminating distances between error correction codes by mixing error correction codes with product codes

for varying error correction capability. Hence, a more multi-level signal can be transmitted.

In fact, a D_1 channel is divided into two sub channels D_{1-1} and D_{1-2} and a D_2 channel is divided into two sub channels D_{2-1} and D_{2-2}.

This will be explained in more detail referring to Fig. 87 in which D_{1-1} is reproduced from a lowest C/N signal. If the C/N rate is d at minimum, three components D_{1-2}, D_{2-1}, and D_{2-2} cannot be reproduced while D_{1-1} is reproduced. If C/N is not less than c, D_{1-2} can also be reproduced. Equally, when C/N is b, D_{2-1} is reproduced and when C/N is a, D_{2-2} is reproduced. As the C/N rate increases, the reproducible signal levels are increased in number. The lower the C/N, the fewer the reproducible signal levels. This will be explained in the form of relation between transmitting distance and reproducible C/N value referring to Fig. 86. In common, the C/N value of a received signal is decreased in proportion to the distance of transmission as expressed by the real line 861 in Fig. 86. It is now assumed that the distance from a transmitter antenna to a

receiver antenna is La when C/N=a, Lb when C/N=b, Lc when C/N=c, Ld when C/N=d, and Le when C/N=e. If the distance from the transmitter antenna is greater than Ld, D_{1-1} can be reproduced as shown in Fig. 85 where the receivable area 862 is denoted by the hatching. In other words, D_{1-1} can be reproduced within a most extended area. Similarly, D_{1-2} can be reproduced in an area 863 when the distance is not more than Lc. In this area 863 containing the area 862, D_{1-1} can with no doubt be reproduced. In a smaller area 854, D_{2-1} can be reproduced and in a smallest area 865, D_{2-2}- can be reproduced. As understood, the different data levels of a channel can be reproduced corresponding to degrees of declination in the C/N rate. The logic multi-level arrangement of the signal transmission system of the present invention can provide the same effect as of a traditional analog transmission system in which the amount of receivable data is gradually lowered as the C/N rate decreases.

The construction of the logic multi-level arrangement will be described in which there are provided two physical levels and two logic levels. Fig. 87 is a block diagram of

a transmitter 1 which is substantially identical in construction to that shown in Fig. 2 and described previously in the first embodiment and will no further be explained in detail. The only difference is that error correction code encoders are added as abbreviated to ECC encoders. The divider circuit 3 has four outputs 1-1, 1-2, 2-1, and 2-2 through which four signals D_{1-1}, D_{1-2}, D_{2-1}, and D_{2-2} divided from an input signal are delivered. The two signals D_{1-1} and D_{1-2} are fed to two, main and sub, ECC encoders 872a, 873a of a first ECC encoder 871a respectively for converting to error correction code forms.

The main ECC encoder 872a has a higher error correction capability than that of the sub ECC encoder 873a. Hence, D_{1-1} can be reproduced at a lower rate of C/N than D_{1-2} as apparent from the CN-level diagram of Fig. 85. More particularly, the logic level of D_{1-1} is less affected by declination of the C/N than that of D_{1-2}. After error correction code encoding, D_{1-1} and D_{1-2} are summed by a summer 874a to a D_1 signal which is then transferred to the modulator 4. The other two signals D_{2-1} and D_{2-2} of the divider circuit 3

are error correction encoded by two, main and sub, ECC encoders 872b, 873b of a second ECC encoder 871b respectively and then, summed by a summer 874b to a D_2 signal which is transferred to the modulator 4. The main ECC encoder 872b is higher in the error correction capability than the sub ECC encoder 873b. The modulator 4 in turn produces from the two, D_1 and D_2, input signals a multi-level modulated signal which is further transmitted from the transmitter unit 5. As understood, the output signal from the transmitter 1 has two physical levels D_1 and D_2 and also, four logic levels D_{1-1}, D_{1-2}, D_{2-1}, and D_{2-2} based on the two physical levels for providing different error correction capabilities.

The reception of such a multi-level signal will be explained. Fig. 88 is a block diagram of a second receiver 33 which is almost identical in construction to that shown in Fig. 21 and described in the first embodiment. The second receiver 33 arranged for intercepting multi-level signals from the transmitter 1 shown in Fig. 87 further comprises a first 876a and a second ECC decoder 876b, in which the demodulation of QAM, or any of ASK, PSK, and FSK

if desired, is executed.

As shown in Fig. 88, a received signal is demodulated by the demodulator 35 to the two, D_1 and D_2, signals which are then fed to two dividers 3a and 3b respectively where they are divided into four logic levels D_{1-1}, D_{1-2}, D_{2-1}, and D_{2-2}. The four signals are transferred to the first 876a and the second ECC decoder 876b in which D_{1-1} is error corrected by a main ECC decoder 877a, D_{1-2} by a sub ECC decoder 878a, D_{2-1} by a main ECC decoder 877b, and D_{2-2} by a sub ECC decoder 878b before all sent to the summer 37. At the summer 37, the four, D_{1-1}, D_{1-2}, D_{2-1}, and D_{2-2}, error corrected signals are summed to a single signal which is then delivered from the output unit 36.

Since D_{1-1} and D_{2-1} are higher in the error correction capability than D_{1-2} and D_{2-2} respectively, the error rate remains less than a given value although C/N is fairly low as shown in Fig. 85 and thus, an original signal will be reproduced successfully.

The action of discriminating the error correction capability between the main ECC decoders 877a, 877b and the

sub ECC decoders 878a, 878b will now be described in mode detail. It is a good idea for having a difference in the error correction capability to use in the sub ECC decoder a common coding technique, e.g. Reed-Solomon or BCH method, having a standard code distance and in the main ECC decoder, another encoding technique in which the distance between error correction codes is increased using Reed-Solomon codes, their product codes, or other long-length codes. A variety of known techniques for increasing the error correction code distance have been introduced and will no more explained. The present invention can be associated with any known technique for having the logic multi-level arrangement.

The logic multi-level arrangement will be explained in conjunction with a diagram of Fig. 89 showing the relation between C/N and error rate after error correction. As shown, the straight line 881 represents D_{1-1} at the C/N and error rate relation and the line 882 represents D_{1-2} at the same.

As the C/N rate of an input signal decreases, the error

rate increases after error correction. If C/N is lower than a given value, the error rate exceeds a reference value Eth determined by the system design standards and no original data will normally be reconstructed. When C/N is lowered to less than e, the D_1 signal fails to be reproduced as expressed by the line 881 of D_{1-1} in Fig. 89. When $e \leq C/N<d$, D_{1-1} of the D_1 signal exhibits a higher error rate than Eth and will not be reproduced.

When C/N is d at the point 885d, D_{1-1} having a higher error correction capability than D_{1-2} becomes not higher in the error rate than Eth and can be reproduced. At the time, the error rate of D_{1-2} remains higher than Eth after error correction and will no longer be reproduced.

When C/N is increased up to c at the point 885c, D_{1-2} becomes not higher in the error rate than Eth and can be reproduced. At the time, D_{2-1} and D_{2-2} remain in no demodulation state. After the C/N rate is increased further to b', the D_2 signal becomes ready to be demodulated.

When C/N is increased to b at the point 885b, D_{2-1} of the D_2 signal becomes not higher in the error rate than Eth

and can be reproduced. At the time, the error rate of D_{2-2} remains higher than Eth and will not be reproduced. When C/N is increased up to a at the point 885a, D_{2-2} becomes not higher than Eth and can be reproduced.

As described above, the four different signal logic levels divided from two, D_1 and D_2, physical levels through discrimination of the error correction capability between the levels, can be transmitted simultaneously.

Using the logic multi-level arrangement of the present invention in accompany with a multi-level construction in which at least a part of the original signal is reproduced even if data in a higher level is lost, digital signal transmission will successfully be executed without losing the advantageous effect of an analog signal transmission in which transmitting data is gradually decreased as the C/N rate becomes low.

Thanking to up-to-date image data compression techniques, compressed image data can be transmitted in the logic multi-level arrangement for enabling a receiver station to reproduce a higher quality image than that of an

analog system and also, with not sharply but at steps declining the signal level for ensuring signal interception in a wider area. The present invention can provide an extra effect of the multi-layer arrangement which is hardly implemented by a known digital signal transmission system without deteriorating high quality image data.

Embodiment 3

A third embodiment of the present invention will be described referring to the relevant drawings.

Fig. 29 is a schematic total view illustrating the third embodiment in the form of a digital TV broadcasting system. An input video signal 402 of super high resolution TV image is fed to an input unit 403 of a first video encoder 401. Then, the signal is divided by a divider circuit 404 into three, first, second, and third, data streams which are transmitted to a compressing circuit 405 for data compression before further delivered.

Equally, other three input video signals 406, 407, and 408 are fed to a second 409, a third 410, and a fourth video encoder 411 respectively which all are arranged identical in

construction to the first video encoder 401 for data compression.

The four first data streams from their respective encoders 401, 409, 410, 411 are transferred to a first multiplexer 413 of a multiplexer 412 where they are time multiplexed by TDM process to a first data stream multiplex signal which is fed to a transmitter 1.

A part or all of the four second data streams from their respective encoders 401, 409, 410, 411 are transferred to a second multiplexer 414 of the multiplexer 412 where they are time multiplexed to a second data stream multiplex signal which is then fed to the transmitter 1. Also, a part or all the four third data streams are transferred to a third multiplexer 415 where they are time multiplexed to a third data stream multiplex signal which is then fed to the transmitter 1.

The transmitter 1 performs modulation of the three data stream signals with its modulator 4 by the same manner as described in the first embodiment. The modulated signals are sent from a transmitter unit 5 through an antenna 6 and

an uplink 7 to a transponder 12 of a satellite 10 which in turn transmits it to three different receivers including a first receiver 23.

The modulated signal transmitted through a downlink 21 is intercepted by a small antenna 22 having a radius r_1 and fed to a first data stream reproducing unit 232 of the first receiver 23 where its first data stream only is demodulated. The demodulated first data stream is then converted by a first video decoder 421 to a traditional 425 or wide-picture NTSC or video output signal 426 of low image resolution.

Also, the modulated signal transmitted through a downlink 31 is intercepted by a medium antenna 32 having a radius r_2 and fed to a first 232 and a second data stream reproducing unit 233 of a second receiver 33 where its first and second data streams are demodulated respectively. The demodulated first and second data streams are then summed and converted by a second video decoder 422 to an HDTV or video output signal 427 of high image resolution and/or to the video output signals 425 and 426.

Also, the modulated signal transmitted through a down-

link 41 is intercepted by a large antenna 42 having a radius r_3 and fed to a first 232, a second 233, and a third data stream reproducing unit 234 of a third receiver 43 where its first, second, and third data streams are demodulated respectively. The demodulated first, second, and third data streams are then summed and converted by a third video decoder 423 to a super HDTV or video output signal 428 of super high resolution for use in a video theater or cinema. The video output signals 425, 426, and 427 can also be reproduced if desired. A common digital TV signal is transmitted from a conventional digital transmitter 51 and when intercepted by the first receiver 23, will be converted to the video output signal 426 such as a low resolution NTSC TV signal.

The first video encoder 401 will now be explained in more detail referring to the block diagram of Fig. 30. An input video signal of super high resolution is fed through the input unit 403 to the divider circuit 404 where it is divided into four components by sub-band coding process. In more particular, the input video signal is separated through

passing a horizontal lowpass filter 451 and a horizontal highpass filter 452 of e.g. QMF mode to two, low and high, horizontal frequency components which are then subsampled to a half of their quantities by two subsamplers 453 and 454 respectively. The low horizontal component is filtered by a vertical lowpass filter 455 and a vertical highpass filter 456 to a low horizontal low vertical component or $H_L V_L$ signal and a low horizontal high vertical component or $H_L V_H$ signal respectively. The two, $H_L V_L$ and $H_L V_H$, signals are then subsampled to a half by two subsampler 457 and 458 respectively and transferred to the compressing circuit 405.

The high horizontal component is filtered by a vertical lowpass filter 459 and a vertical highpass filter 460 to a high horizontal low vertical component or $H_H V_L$ signal and a high horizontal high vertical component or $H_H V_H$ signal respectively. The two, $H_H V_L$ and $H_H V_H$, signals are then subsampled to a half by two subsampler 461 and 462 respectively and transferred to the compressing circuit 405.

$H_L V_L$ signal is preferably DCT compressed by a first compressor 471 of the compressing circuit 405 and transmit-

ted from a first output 405 as the first data stream.

Also, H_LV_H signal is compressed by a second compressor 473 and fed to a second output 464. H_HV_L signal is compressed by a third compressor 463 and fed to the second output 464. H_HV_H signal is divided by a divider 465 into two, high resolution (H_HV_H1) and super high resolution (H_HV_H2), video signals which are then transferred to the second output 464 and a third output 468 respectively.

The first video decoder 421 will now be explained in more detail referring to Fig. 31. The first data stream or D_1 signal of the first receiver 23 is fed through an input unit 501 to a descrambler 502 of the first video decoder 421 where it is descrambled. The descrambled D_1 signal is expanded by an expander 503 to H_LV_L which is then fed to an aspect ratio changing circuit 504. Thus, H_LV_L signal can be delivered through and output unit 505 as a standard 500, letterbox format 507, wide-screen 508, or sidepanel format NTSC signal 509. The scanning format may be of non-interlace or interlace type and its NTSC mode lines may be 525 or doubled to 1050 by double tracing. When the received signal

from the digital transmitter 51 is a digital TV signal of 4 PSK mode, it can also be converted by the first receiver 23 and the first video decoder 421 to a TV picture. The second video decoder 422 will be explained in more detail referring to the block diagram of Fig. 32. The D_1 signal of the second receiver 33 is fed through a first input 521 to a first expander 522 for data expansion and then, transferred to an oversampler 523 where it is sampled at 2x. The over-sampled signal is filtered by a vertical lowpass filter 524 to H_LV_L. Also, the D_2 signal of the second receiver 33 is fed through a second input 530 to a divider 531 where it is divided into three components which are then transferred to a second 532, a third 533, and a fourth expander 534 respectively for data expansion. The three expanded components are sampled at 2x by three oversamplers 535, 536, 537 and filtered by a vertical highpass 538, a vertical lowpass 539, and a vertical highpass filter 540 respectively. Then, H_LV_L from the vertical lowpass filter 524 and H_LV_H from the vertical highpass filter 538 are summed by an adder 525, sampled by an oversampler 541, and filtered by horizontal

lowpass filter 542 to a low frequency horizontal video signal. $H_H V_L$ from the vertical lowpass filter 539 and $H_H V_H 1$ from the vertical highpass filter 540 are summed by an adder 526, sampled by an oversampler 544, and filtered by horizontal highpass filter 545 to a high frequency horizontal video signal. The two, high and low frequency, horizontal video signal are then summed by an adder 543 to a high resolution video signal HD which is further transmitted through an output unit 546 as a video output 547 of e.g. HDTV format. If desired, a traditional NTSC video output can be reconstructed with equal success.

Fig. 33 is a block diagram of the third video decoder 423 in which the D_1 and D_2 signals are fed through a first 521 and a second input 530 respectively to a high frequency band video decoder circuit 527 where they are converted to an HD signal by the same manner as above described. The D_3 signal is fed through a third input 551 to a super high frequency band video decoder circuit 552 where it is expanded, descrambled, and composed to $H_H V_H 2$ signal. The HD signal of the high frequency band video decoder circuit 527

and the $H_H V_H 2$ signal of the super high frequency band video decoder circuit 552 are summed by a summer 553 to a super high resolution TV or S-HD signal which is then delivered through an output unit 554 as a super resolution video output 555.

The action of multiplexing in the multiplexer 412 shown in Fig. 29 will be explained in more detail. Fig. 34 illustrates a data assignment in which the three, first, second, and third, data streams D_1, D_2, D_3 contain in a period of T six NTSC channel data L1, L2, L3, L4, L5, L6, six HDTV channel data M1, M2, M3, M4, M5, M6 and six S-HDTV channel data H1, H2, H3, H4, H5, H6 respectively. In action, the NTSC or D_1 signal data L1 to L6 are time multiplexed by TDM process during the period T. More particularly, $H_L V_L$ of D_1 is assigned to a domain 601 for the first channel. Then, a difference data M1 between HDTV and NTSC or a sum of $H_L V_H$, $H_H V_L$, and $H_H V_H 1$ is assigned to a domain 602 for the first channel. Also, a difference data H1 between HDTV and super HDTV or $H_H V_H 2$ (See Fig. 30) is assigned to a domain 603 for the first channel.

The selection of the first channel TV signal will now be described. When intercepted by the first receiver 23 with a small antenna coupled to the first video decoder 21, the first channel signal is converted to a standard or widescreen NTSC TV signal as shown in Fig. 31. When intercepted by the second receiver 33 with a medium antenna coupled to the second video decoder 422, the signal is converted by summing L1 of the first data stream D_1 assigned to the domain 601 and M1 of the second data stream D_2 assigned to the domain 602 to an HDTV signal of the first channel equivalent in program to the NTSC signal.

When intercepted by the third receiver 43 with a large antenna coupled to the third video decoder 423, the signal is converted by summing L1 of D_1 assigned to the domain 601, M1 of D_2 assigned to the domain 602, and H1 of D_3 assigned to the domain 603 to a super HDTV signal of the first channel equivalent in program to the NTSC signal. The other channel signals can be reproduced in an equal manner.

Fig. 35 shows another data assignment in which L1 of a first channel NTSC signal is assigned to a first domain 601.

The domain 601 which is allocated at the front end of the first data stream D_1, also contains at front a data S11 including a descrambling data and the demodulation data described in the first embodiment. A first channel HDTV signal is transmitted as L1 and M1. M1 which is thus a difference data between NTSC and HDTV is assigned to two domains 602 and 611 of D_2. If L1 is a compressed NTSC component of 6 Mbps, M1 is as two times higher as 12 Mbps. Hence, the total of L1 and M1 can be demodulated at 18 Mbps with the second receiver 33 and the second video decoder 423. According to current data compression techniques, HDTV compressed signals can be reproduced at about 15 Mbps. This allows the data assignment shown in Fig. 35 to enable simultaneous reproduction of an NTSC and an HDTV first channel signal. However, this assignment allows no second channel HDTV signal to be carried. S21 is a descrambling data in the HDTV signal. A first channel super HDTV signal component comprises L1, M1, and H1. The difference data H1 is assigned to three domains 603, 612, and 613 of D_3. If the NTSC signal is 6 Mbps, the super HDTV is carried at as high

as 36 Mbps. When a compression rate is increased, super HDTV video data of about 2000 scanning line for reproduction of a cinema size picture for commercial use can be transmitted with an equal manner.

Fig. 36 shows a further data assignment in which H1 of a super HDTV signal is assigned to six time domains. If a NTSC compressed signal is 6 Mbps, this assignment can carry as nine times higher as 54 Mbps of D_3 data. Accordingly, super HDTV data of higher picture quality can be transmitted.

The foregoing data assignment makes the use of one of two, horizontal and vertical, polarization planes of a transmission wave. When both the horizontal and vertical polarization planes are used, the frequency utilization will be doubled. This will be explained below.

Fig. 49 shows a data assignment in which D_{V1} and D_{H1} are a vertical and a horizontal polarization signal of the first data stream respectively, D_{V2} and D_{H2} are a vertical and a horizontal polarization signal of the second data stream respectively, and D_{V3} and D_{H3} are a vertical and a

horizontal polarization signal of the third data stream respectively. The vertical polarization signal D_{V1} of the first data stream carries a low frequency band or NTSC TV data and the horizontal polarization signal D_{H1} carries a high frequency band or HDTV data. When the first receiver 23 is equipped with a vertical polarization antenna, it can reproduce only the NTSC signal. When the first receiver 23 is equipped with an antenna for both horizontally and vertically polarized waves, it can reproduce the HDTV signal through summing L1 and M1. More specifically, the first receiver 23 can provide compatibility between NTSC and HDTV with the use of a particular type antenna.

Fig. 50 illustrates a TDMA method in which each data burst 721 is accompanied at front a sync data 731 and a card data 471. Also, a frame sync data 720 is provided at the front of a frame. Like channels are assigned to like time slots. For example, a first time slot 750 carries NTSC, HDTV and super HDTV data of the first channel simultaneously. The six time slots 750, 750a, 750b, 750c, 750d, 750e are arranged independent from each other. Hence, each

station can offer NTSC, HDTV, and/or super HDTV services independently of the other stations through selecting a particular channel of the time slots. Also, the first receiver 23 can reproduce an NTSC signal when equipped with a horizontal polarization antenna and both NTSC and HDTV signals when equipped with a compatible polarization antenna. In this respect, the second receiver 33 can reproduce a super HDTV at lower resolution while the third receiver 43 can reproduce a full super HDTV signal. According to the third embodiment, a compatible signal transmission system will be constructed. It is understood that the data assignment is not limited to the burst mode TDMA method shown in Fig. 50 and another method such as time division multiplexing of continuous signals as shown in Fig. 49 will be employed with equal success. Also, a data assignment shown in Fig. 51 will permit a HDTV signal to be reproduced at high resolution.

As set forth above, the compatible digital TV signal transmission system of the third embodiment can offer three, super HDTV, HDTV, and conventional NTSC, TV broadcast serv-

ices simultaneously. In addition, a video signal intercepted by a commercial station or cinema can be electronized.

Embodiment 4

A fourth embodiment of the present invention will be described referring to the relevant drawings.

Fig. 37 illustrates the entire arrangement of a signal transmission system of the fourth embodiment, which is arranged for terrestrial service and similar in both construction and action to that of the third embodiment shown in Fig. 29. The difference is that the transmitter antenna 6 is replaced with a terrestrial antenna 6a and the receiver antennas 22, 32, 42 are replaced with also three terrestrial antennas 22a, 32a, 42a. The action of the system is identical to that of the third embodiment and will no more be explained. The terrestrial broadcast service unlike a satellite service depends much on the distance between the transmitter antenna 6a to the receiver antenna 22a, 32a, 42a. If a receiver is located far from the transmitter, the level of a received signal is low. Particularly, a common multi-level QAM signal can hardly be demodulated by the

receiver which thus reproduces no TV program.

The signal transmission system of the present invention allows the first receiver 23 equipped with the antenna 22a, which is located at a far distance as shown in Fig. 37, to intercept a modified 16 or 64 QAM signal and demodulate at 4 PSK mode the first data stream or D_1 component of the received signal to an NTSC video signal so that a TV program picture of medium resolution can be displayed even if the level of the received signal is relatively low.

Also, the second receiver 33 with the antenna 32a is located at a medium distance from the antenna 6a and can thus intercept and demodulate both the first and second data streams or D_1 and D_2 components of the modified 16 or 64 QAM signal to an HDTV video signal which in turn produces an HDTV program picture.

The third receiver 43 with the antenna 42a is located at a near distance and can intercept and demodulate the first, second, and third data streams or D_1, D_2, and D_3 components of the modified 16 or 64 QAM signal to a super HDTV video signal which in turn produces a super HDTV pic-

ture equal in quality to a common movie picture.

The assignment of frequencies is determined by the same manner as of the time division multiplexing shown in Figs. 34, 35, and 36. Like Fig. 34, when the frequencies are assigned to first to sixth channels, L1 of the D_1 component carries an NTSC data of the first channel, M1 of the D_2 component carries an HDTV difference data of the first channel, and H1 of the D_3 component carries a super HDTV difference data of the first channel. Accordingly, NTSC, HDTV, and super HDTV data all can be carried on the same channel. If D_2 and D_3 of the other channels are utilized as shown in Figs. 35 and 36, more data of HDTV and super HDTV respectively can be transmitted for higher resolution display.

As understood, the system allows three different but compatible digital TV signals to be carried on a single channel or using D_2 and D_3 regions of the other channels. Also, the medium resolution TV picture data of each channel can be intercepted in a wider service area according to the present invention.

A variety of terrestrial digital TV broadcast systems employing a 16 QAM HDTV signal of 6 MHz bandwidth have been proposed. Those are however not compatible with the existing NTSC system and thus, have to be associated with a simulcast technique for transmitting NTSC signals of the same program on another channel. Also, such a common 16 QAM signal limits a service area. The terrestrial service system of the present invention allows a receiver located at a relatively far distance to intercept successfully a medium resolution TV signal with no use of an additional device nor an extra channel.

Fig. 52 shows an interference region of the service area 702 of a conventional terrestrial digital HDTV broadcast station 701. As shown, the service area 702 of the conventional HDTV station 701 is intersected with the service area 712 of a neighbor analog TV station 711. At the intersecting region 713, an HDTV signal is attenuated by signal interference from the analog TV station 711 and will thus be intercepted with less consistency.

Fig. 53 shows an interference region associated with

the multi-level signal transmission system of the present invention. The system is low in the energy utilization as compared with a conventional system and its service area 703 for HDTV signal propagation is smaller than the area 702 of the conventional system. In contrary, the service area 704 for digital NTSC or medium resolution TV signal propagation is larger than the conventional area 702. The level of signal interference from a digital TV station 701 of the system to a neighbor analog TV station 711 is equivalent to that from a conventional digital TV station, such as shown in Fig. 52.

In the service area of the digital TV station 701, there are three interference regions developed by signal interference from the analog TV station 711. Both HDTV and NTSC signals can hardly be intercepted in the first region 705. Although fairly interfered, an NTSC signal may be intercepted at an equal level in the second region 706 denoted by the left down hatching. The NTSC signal is carried on the first data stream which can be reproduced at a relatively low C/N rate and will thus be minimum affected

when the C/N rate is declined by signal interference from the analog TV station 711.

At the third region 707 denoted by the right down hatching, an HDTV signal can also be intercepted when signal interference is absent while the NTSC signal can constantly be intercepted at a level.

Accordingly, the overall signal receivable area of the system will be increased although the service area of HDTV signals becomes a bit smaller than that of the conventional system. Also, at the signal attenuating regions produced by interference from a neighbor analog TV station, NTSC level signals of an HDTV program can successfully be intercepted as compared with the conventional system where no HDTV program is viewed in the same area. The system of the present invention much reduces the size of signal attenuating areas and when increases the energy of signal transmission at a transmitter or transponder station, can extend the HDTV signal service area to an equal size to the conventional system. Also, NTSC level signals of a TV program can be intercepted more or less in a far distant area where no

service is given by the conventional system or a signal interference area caused by an adjacent analog TV station.

Although the embodiment employs a two-level signal transmission method, a three-level method such as shown in Fig. 78 will be used with equal success. If an HDTV signal is divided into three picture levels-HDTV, NTSC, and low resolution NTSC, the service area shown in Fig. 53 will be increased from two levels to three levels where the signal propagation is extended radially and outwardly. Also, low resolution NTSC signals can be received at an acceptable level at the first signal interference region 705 where NTSC signals are hardly be intercepted in the two-level system. As understood, the signal interference is also involved from a digital TV station to an analog TV station.

The description will now be continued, provided that no digital TV station should cause a signal interference to any neighbor analog TV station. According to a novel system under consideration in U.S.A., no-use channels of the existing service channels are utilized for HDTV and thus, digital signals must not interfere with analog signals. For the

purpose, the transmitting level of a digital signal has to be decreased lower than that shown in Fig. 53. If the digital signal is of conventional 16 QAM or 4 PSK mode, its HDTV service area 708 becomes decreased as the signal interference region 713 denoted by the cross hatching is fairly large as shown in Fig. 54. This results in a less number of viewers and sponsors, whereby such a digital system will have much difficulty to operate for profitable business.

Fig. 55 shows a similar result according to the system of the present invention. As apparent, the HDTV signal receivable area 703 is a bit smaller than the equal area 708 of the conventional system. However, the lower resolution or NTSC TV signal receivable area 704 will be increased as compared with the conventional system. The hatching area represents a region where the NTSC level signal of a program can be received while the HDTV signal of the same is hardly intercepted. At the first interference region 705, both HDTV and NTSC signals cannot be intercepted due to signal interference from an analog station 711.

When the level of signals is equal, the multi-level

transmission system of the present invention provides a smaller HDTV service area and a greater NTSC service area for interception of an HDTV program at an NTSC level signal. Accordingly, the overall service area of each station is increased and more viewers can enjoy its TV broadcasting service. Furthermore, HDTV/NTSC compatible TV business can be operated with economical advantages and consistency. It is also intended that the level of a transmitting signal is increased when the control on averting signal interference to neighbor analog TV stations is lessened corresponding to a sharp increase in the number of home-use digital receivers. Hence, the service area of HDTV signals will be increased and in this respect, the two different regions for interception of HDTV/NTSC and NTSC digital TV signal levels respectively, shown in Fig. 55, can be adjusted in proportion by varying the signal point distance in the first and/or second data streams. As the first data stream carries information about the signal point distance, a multilevel signal can be received with more certainty.

Fig. 56 illustrates signal interference between two

digital TV stations in which a neighbor TV station 701a also provides a digital TV broadcast service, as compared with an analog station in Fig. 52. Since the level of a transmitting signal becomes high, the HDTV service or high resolution TV signal receivable area 703 becomes is increased to an extension equal to the service area 702 of an analog TV system.

At the intersecting region 714 between two service areas of their respective stations, the received signal can be reproduced not to an HDTV level picture with the use of a common directional antenna due to signal interference but to an NTSC level picture with a particular directional antenna directed towards a desired TV station. If a highly directional antenna is used, the received signal from a target station will be reproduced to an HDTV picture. The low resolution signal receivable area 704 is increased larger than the analog TV system service area 702 and a couple of intersecting regions 715, 716 developed by the two low resolution signal receivable areas 704 and 704a of their respective digital TV stations 701 and 701a permit the

received signal from antenna directed one of the two stations to be reproduced to an NTSC level picture.

The HDTV service area of the multi-level signal transmission system of the present invention itself will be much increased when applicable signal restriction rules are withdrawn in a coming digital TV broadcast service maturity time. At the time, the system of the present invention also provides as a wide HDTV signal receivable area as of the conventional system and particularly, allows its transmitting signal to be reproduced at an NTSC level in a further distant or intersecting areas where TV signals of the conventional system are hardly intercepted. Accordingly, signal attenuating or shadow regions in the service area will be minimized.

Embodiment 5

A fifth embodiment of the present invention resides in amplitude modulation or ASK procedure. Fig. 57 illustrates the assignment of signal points of a 4-level ASK signal according to the fifth embodiment, in which four signal points are denoted by 721, 722, 723, and 724. The four-

level transmission permits a 2-bit data to be transmitted in every cycle period. It is assumed that the four signal points 721, 722, 723, 724 represent two-bit patterns 00, 01, 10, 11 respectively.

For ease of four-level signal transmission of the embodiment, the two signal points 721, 722 are designated as a first signal point group 725 and the other two 723, 724 are designated as a second signal point group 726. The distance between the two signal point groups 725 and 726 is then determined wider than that between any two adjacent signal points. More specifically, the distance Lo between two signals 722 and 723 is arranged wider than the distance L between the two adjacent points 721 and 722 or 723 and 724. This is expressed as:

$$Lo > L$$

Hence, the multi-level signal transmission system of the embodiment is based on Lo > L. The embodiment is however not limited to Lo > L and L = Lo will be employed temporarily or permanently depending on the requirements of design, condition, and setting.

The two signal point groups are assigned one-bit patterns of the first data stream D_1, as shown in Fig. 59-a. More particularly, a bit 0 of binary system is assigned to the first signal point group 725 and another bit 1 to the second signal point group 726. Then, a one-bit pattern of the second data stream D_2 is assigned to each signal point. For example, the two signal points 721, 723 are assigned $D_2=0$ and the other two signal points 722 and 724 are assigned $D_2=1$. Those are thus expressed by two bits per symbol.

The multi-level signal transmission of the present invention can be implemented in an ASK mode with the use of the foregoing signal point assignment. The system of the present invention works in the same manner as of a conventional equal signal point distance technique when the signal to noise ratio or C/N rate is high. If the C/N rate becomes low and no data can be reproduced by the conventional technique, the present system ensures reproduction of the first data stream D_1 but not the second data stream D_2. In more detail, the state at a low C/N is shown in Fig. 60. The

signal points transmitted are displaced by a Gaussian distribution to ranges 712a, 722a, 723a, 724a respectively at the receiver side due to noise and transmission distortion. Therefore, the distinction between the two signals 721 and 722 or 723 and 724 will hardly be executed. In other words, the error rate in the second data stream D_2 will be increased. As apparent from Fig. 60, the two signal points 721, 722 are easily distinguished from the other two signal points 723, 724. The distinction between the two signal point groups 725 and 726 can thus be carried out with ease. As the result, the first data stream D_1 will be reproduced at a lower error rate.

Accordingly, the two different level data D_1 and D_2 can be transmitted simultaneously. More particularly, both the first and second data streams D_1 and D_2 of a given signal transmitted through the multi-level transmission system can be reproduced at the area where the C/N rate is high and the first data stream D_1 only can be reproduced in the area where the C/N rate is low.

Fig. 61 is a block diagram of a transmitter 741 in

which an input unit 742 comprises a first data stream input 743 and a second data stream input 744. A carrier wave from a carrier generator 64 is amplitude modulated by a multiplier 746 using an input signal fed across a processor 745 from the input unit 743. The modulated signal is then band limited by a filter 747 to an ASK signal of e.g. VSB mode which is then delivered from an output unit 748.

The waveform of the ASK signal after filtering will now be examined. Fig. 62-a shows a frequency spectrum of the ASK modulated signal in which two sidebands are provided on both sides of the carrier frequency band. One of the two side-bands is eliminated with the filter 474 to produce a signal 749 which contains a carrier component as shown in Fig. 62-b. The signal 749 is a VSB signal and if the modulation frequency band is fo, will be transmitted in a frequency band of about fo/2. Hence, the frequency utilization becomes high. Using VSB mode transmission, the ASK signal of two bit per symbol shown in Fig. 60 can thus carry in the frequency band an amount of data equal to that of 16 QAM mode at four bits per symbol.

Fig. 63 is a block diagram of a receiver 751 in which an input signal intercepted by a terrestrial antenna 32a is transferred through an input unit 752 to a mixer 753 where it is mixed with a signal from a variable oscillator 754 controlled by channel selection to a lower medium frequency signal. The signal from the mixer 753 is then detected by a detector 755 and filtered by an LPF 756 to a baseband signal which is transferred to a discriminating/reproduction circuit 757. The discrimination/reproduction circuit 757 reproduces two, first D_1 and second D_2, data streams from the baseband signal and transmit them further through a first 758 and a second data stream output 759 respectively.

The transmission of a TV signal using such a transmitter and a receiver will be explained. Fig. 64 is a block diagram of a video signal transmitter 774 in which a high resolution TV signal, e.g. an HDTV signal, is fed through an input unit 403 to a divider circuit 404 of a first video encoder 401 where it is divided into four high/low frequency TV signal components denoted by e.g. H_LV_L, H_LV_H, H_HV_L, and H_HV_H. This action is identical to that of the third embodi-

ment previously described referring to Fig. 30 and will no more be explained in detail. The four separate TV signals are encoded respectively by a compressor 405 using a known DPCMDCT variable length code encoding technique which is commonly used e.g. in MPEG. Meanwhile, the motion compensation of the signal is carried out at the input unit 403. The compressed signals are summed by a summer 771 to two, first and second, data streams D_1, D_2. The low frequency video signal component or H_LV_L signal is contained in the first data stream D_1. The two data stream signals D_1, D_2 are then transferred to a first 743 and a second data stream input 744 of a transmitter unit 741 where they are amplitude modulated and summed to an ASK signal of e.g. VSB mode which is propagated from a terrestrial antenna for broadcast service.

Fig. 65 is a block diagram of a TV receiver for such a digital TV broadcast system. A digital TV signal intercepted by a terrestrial antenna 32a is fed to an input 752 of a receiver unit 751 in the TV receiver 781. The signal is then transferred to a detection/demodulation circuit 760

where a desired channel signal is selected and demodulated to two, first and second, data streams D_1, D_2 which are then fed to a first 758 and a second data stream output 759 respectively. The action in the receiver unit 751 is similar to that described previously and will no more be explained in detail. The two data streams D_1, D_2 are sent to a divider unit 776 in which D_1 is divided by a divider 777 into two components; one or compressed H_LV_L is transferred to a first input 521 of a second video decoder 422 and the other is fed to a summer 778 where it is summed with D_2 prior to transfer to a second input 531 of the second video decoder 422. Compressed H_LV_L is then sent from the first input 521 to a first expander 523 where it is expanded to H_LV_L of the original length which is then transferred to a video mixer 548 and a aspect ratio changing circuit 779. When the input TV signal is an HDTV signal, H_LV_L represents a wide-screen NTSC signal. When the same is an NTSC signal, H_LV_L represents a lower resolution video signal, e.g. MPEG1, than an NTSC level.

The input TV signal of the embodiment is an HDTV signal

and $H_L V_L$ becomes a wide-screen NTSC signal. If the aspect ratio of an available display is 16:9, $H_L V_L$ is directly delivered through an output unit as a 16:9 video output 426. If the display has an aspect ratio of 4:3, $H_L V_L$ is shifted by the aspect ratio changing circuit 779 to a letterbox or sidepanel format and then, delivered from the output unit 780 as a corresponding format video output 425.

The second data stream D_2 fed from the second data stream output 759 to the summer 778 is summed with the output of the divider 777 to a sum signal which is then fed to the second input 531 of the second video decoder 422. The sum signal is further transferred to a divider circuit 531 where it is divided into three compressed forms $H_L V_H$, $H_H V_L$, and $H_H V_H$. The three compressed signals are then fed to a second 535, a third 536, and a fourth expander 537 respectively for converting by expansion to $H_L V_H$, $H_H V_L$, and $H_H V_H$ of the original length. The three signals are summed with $H_L V_L$ by the video mixer 548 to a composite HDTV signal which is fed through an output 546 of the second video decoder to the output unit 780. Finally, the HDTV signal is

delivered from the output unit 780 as an HDTV video signal 427.

The output unit 780 is arranged for detect an error rate in the second data stream of the second data stream output 759 through an error rate detector 782 and if the error rate is high, delivering $H_L V_L$ of low resolution video data systematically.

Accordingly, the multi-level signal transmission system for digital TV signal transmission and reception becomes feasible. For example, if a TV signal transmitter station is near, both the first and second data streams of a received signal can successfully be reproduced to exhibit an HDTV quality picture. If the transmitter station is far, the first data stream can be reproduced to $H_L V_L$ which is converted to a low resolution TV picture. Hence, any TV program will be intercepted in a wider area and displayed at a picture quality ranging from HDTV to NTSC level.

Fig. 66 is a block diagram showing another arrangement of the TV receiver. As shown, the receiver unit 751 contains only a first data stream output 768 and thus, the

processing of the second data stream of HDTV data is not needed so that the overall construction can be minimized. It is a good idea to have the first video decoder 421 shown in Fig. 31 as a video decoder of the receiver. Accordingly, an NTSC level picture will be reproduced. The receiver is fabricated at much less cost as having no capability to receive any HDTV level signal and will widely be accepted in the market. In brief, the receiver can be used as an adapter tuner for interception of a digital TV signal with giving no modification to the existing TV system including a display.

The TV receiver 781 may have a further arrangement shown in Fig. 67, which serves as both a satellite broadcast receiver for demodulation of PSK signals and a terrestrial broadcast receiver for demodulation of ASK signals. In action, a PSK signal received by a satellite antenna 32 is mixed by a mixer 786 with a signal from an oscillator 787 to a low frequency signal which is then fed through an input unit 34 to a mixer 753 similar to one shown in Fig. 63. The low frequency signal of PSK or QAM mode in a given channel

of the satellite TV system is transferred to a modulator 35 where two data streams D_1 and D_2 are reproduced from the signal. D_1 and D_2 are sent through a divider 788 to a second video decoder 422 where they are converted to a video signal which is then delivered from an output unit 780. Also, a digital or analog terrestrial TV signal intercepted by a terrestrial antenna 32a is fed through an input unit 752 to the mixer 753 where one desired channel is selected by the same manner as described in Fig. 63 and detected to a low frequency baseband signal. The signal of analog form is sent directly to the demodulator 35 for demodulation. The signal of digital form is then fed to a discrimination/ reproducing circuit 757 where two data streams D_1 and D_2 are reproduced from the signal. D_1 and D_2 are converted by the second video decoder 422 to a video signal which is then delivered further. A satellite analog TV signal is transferred to a video demodulator 788 where it is AM demodulated to an analog video signal which is then delivered from the output unit 780. As understood, the mixer 753 of the TV receiver 781 shown in Fig. 67 is arranged compatible between

two, satellite and terrestrial, broadcast services. Also, a receiver circuit including a detector 755 and an LPF 756 for AM demodulation of an analog signal can be utilized compatible with a digital ASK signal of the terrestrial TV service. The major part of the arrangement shown in Fig. 67 is arranged for compatible use, thus minimizing a circuitry construction.

According to the embodiment, a 4-level ASK signal is divided into two, D_1 and D_2 level components for execution of the one-bit mode multi-level signal transmission. If an 8-level ASK signal is used as shown in Fig. 68, it can be transmitted in a one-bit mode three-level, D_1, D_2, and D_3, arrangement. As shown in Fig. 68, D_1 is assigned to eight signal points 721a, 721b, 722a, 722b, 723a, 723b, 724a, 724b, each pair representing a two-bit pattern, D_2 is assigned to four small signal point groups 721, 722, 723, 724, each two groups representing a two-bit pattern, and D_3 is assigned to two large signal point groups 725 and 726 representing a two-bit pattern. More particularly, this is equivalent to a form in which each of the four signal points

721, 722, 723, 724 shown in Fig. 57 is divided into two components thus producing three different level data.

The three-level signal transmission is identical to that described in the third embodiment and will no further be explained in detail.

In particular, the arrangement of the video encoder 401 of the third embodiment shown in Fig. 30 is replaced with a modification of which block diagram is Fig. 69. The operation of the modified arrangement is similar and will no longer be explained in detail. Two video signal divider circuits 404 and 404a which may be sub-band filters are provided forming a divider unit 794. The divider unit 794 may also be arranged more simple as shown in the block diagram of Fig. 70, in which a signal passes across one single divider circuit two times at time division mode. Mode specifically, a video signal of e.g. HDTV or super HDTV from the input unit 403 is time-base compressed by a time-base compressor 795 and fed to the divider circuit 404 where it is divided into four components, H_HV_H-H, H_HV_L-H, and H_LV_H-H, and H_LV_L-H at a first cycle. At the time, four

switches 765, 765a, 765b, 765c remain turned to the position 1 so that H_HV_H-H, H_HV_L-H, and H_LV_H-H are transmitted to a compressing circuit 405. Meanwhile, H_LV_L-H is fed back through the terminal 1 of the switch 765c to the time-base compressor 795. At a second cycle, the four switches 765, 765a, 765b, 765c and turned to the position 2 and all the four components of the divider circuit 404 are simultaneously transferred to the compressing circuit 405. Accordingly, the divider unit 794 of Fig. 70 arranged for time division processing of an input signal can be constructed in a simpler dividing circuit form.

At the receiver side, such a video decoder as described in the third embodiment and shown in Fig. 30 is needed for three-level transmission of a video signal. More particularly, a third video decoder 423 is provided which contains two mixers 556 and 556a of different processing capability as shown in the block diagram of Fig. 71.

Also, the third video decoder 423 may be modified in which the same action is executed with one single mixer 556 as shown in Fig. 72. At the first timing, five switches

765, 765a, 765b, 765c, 765d remain turned to the position 1. Hence, H_LV_L, H_LV_H, H_HV_L, and H_HV_H are fed from a first 522, a second 522a, a third 522b and a fourth expander 522c to through their respective switches to the mixer 556 where they are mixed to a single video signal. The video signal which represents H_LV_L-H of an input high resolution video signal is then fed back through the terminal 1 of the switch 765d to the terminal 2 of the switch 765c. At the second timing, the four switches 765, 765a, 765b, 765c are turned to the position 2. Thus, H_HV_H-H, H_HV_L-H, H_LV_H-H, and H_LV_L-H are transferred to the mixer 556 where they are mixed to a single video signal which is then sent across the terminal 2 of the switch 765d to the output unit 554 for further delivery.

In this manner of time division processing of a three-level signal, two mixers can be replaced with one mixer.

More particularly, four components H_LV_L, H_LV_H, H_HV_L, H_HV_H are fed to produce H_LV_L-H at the first timing. Then, H_LV_H-H, H_HV_L-H, and H_HV_H-H are fed at the second timing delayed from the first timing and mixed with H_LV_L-L to a

target video signal. It is thus essential to perform the two actions at an interval of time.

If the four components are overlapped each other or supplied in a variable sequence, they have to be time-base adjusted to a given sequence through using memories accompanied with their respective switches 765, 765a, 765b, 765c. In the foregoing manner, a signal are transmitted from the transmitter at two different timing periods as shown in Fig. 73 so that no time-base controlling circuit is needed in the receiver which is thus arranged more compact.

As shown in Fig. 73, D_1 is the first data stream of a transmitting signal and H_LV_L, H_LV_H, H_HV_L, and H_HV_H are transmitted on D_1 channel at the period of first timing. Then, at the period of second timing, H_LV_H-H, H_HV_L-H, and H_HV_H-H are transmitted on D_2 channel. As the signal is transmitted in a time division sequence, the encoder in the receiver can be arranged more simple.

The technique of reducing the number of the expanders in the decoder will now be explained. Fig. 74-b shows a time-base assignment of four data components 810, 810a,

810b, 810c of a signal. When other four data components 811, 811a, 811b, 811c are inserted between the four data components 811, 811a, 811b, 811c respectively, the latter can be transmitted at intervals of time. In action, the second video decoder 422 shown in Fig. 74-a receives the four components of the first data stream D_1 at a first input 521 and transfers them through a switch 812 to an expander 503 one after another. More particularly, the component 810 first fed is expanded during the feeding of the component 811 and after completion of processing the component 810, the succeeding component 810a is fed. Hence, the expander 503 can process a row of the components at time intervals by the same time division manner as of the mixer, thus substituting the simultaneous action of a number of expanders.

Fig. 75 is a time-base assignment of data components of an HDTV signal, in which $H_LV_L(1)$ of an NTSC component of the first channel signal for a TV program is allocated to a data domain 821 of D_1 signal. Also, H_LV_H, H_HV_L, and H_HV_H carrying HDTV additional components of the first channel signal are allocated to three domains 821a, 821b, 821c of D_2 signal

respectively. There are provided other data components 822, 822a, 822b, 822c between the data components of the first channel signal which can thus be expanded with an expander circuit during transmission of the other data. Hence, all the data components of one channel signal will be processed by a single expander capable of operating at a higher speed.

Similar effects will be ensured by assignment of the data components to other domains 821, 821a, 821b, 821c as shown in Fig. 76. This becomes more effective in transmission and reception of a common 4 PSK or ASK signal having no different digital levels.

Fig. 77 shows a time-base assignment of data components during physical two-level transmission of three different signal level data: e.g. NTSC, HDTV, and super HDTV or low resolution NTSC, standard resolution NTSC, and HDTV. For example, for transmission of three data components of low resolution NTSC, standard NTSC, and HDTV, the low resolution NTSC or H_LV_L is allocated to the data domain 821 of D_1 signal. Also, H_LV_H, H_HV_L, and H_HV_H of the standard NTSC component are allocated to three domains 821a, 821b, 821c

respectively. H_LV_H-H, H_HV_L-H, and H_HV_H-H of the HDTV component are allocated to domains 823, 823a, and 823b respectively.

The foregoing assignment is associated with such a logic level arrangement based on discrimination in the error correction capability as described in the second embodiment. More particularly, H_LV_L is carried on D_{1-1} channel of the D_1 signal. The D_{1-1} channel is higher in the error correction capability than D_{1-2} channel, as described in the second embodiment. The D_{1-1} channel is higher in the redundancy but lower in the error rate than the D_{1-2} channel and the data 821 can be reconstructed at a lower C/N rate than that of the other data 821a, 821b, 821c. More specifically, a low resolution NTSC component will be reproduced at a far location from the transmitter antenna or in a signal attenuating or shadow area, e.g. the interior of a vehicle. In view of the error rate, the data 821 of D_{1-1} channel is less affected by signal interference than the other data 821a, 821b, 821c of D_{1-2} channel, while being specifically discriminated and staying in a different logic level, as de-

scribed in the second embodiment. While D_1 and D_2 are divided into two physically different levels, the levels determined by discrimination of the distance between error correcting codes are arranged different in the logic level.

The demodulation of D_2 data requires a higher C/N rate than that for D_1 data. In action, H_LV_L or low resolution NTSC signal can at least be reproduced in a distant or lowest C/N service area. H_LV_H, H_HV_L, and H_HV_H can in addition be reproduced at a lower C/N area. Then, at a high C/N area, H_LV_H-H, H_HV_L-H, and H_HV_H-H components can also be reproduced to develop an HDTV signal. Accordingly, three different level broadcast signals can be played back. This method allows the signal receivable area shown in Fig. 53 to increase from a double region to a triple region, as shown in Fig. 90, thus ensuring higher opportunity for enjoying TV programs.

Figs. 78 is a block diagram of the third video decoder arranged for the time-based assignment of data shown in Fig. 77, which is similar to that shown in Fig. 72 except that the third input 551 for D_3 signal is eliminated and the

arrangement shown in Fig. 74-a is added.

In operation, both the D_1 and D_2 signals are fed through two input units 521, 530 respectively to a switch 812 at the first timing. As their components including H_LV_L are time divided, they are transferred in a sequence by the switch 812 to an expander 503. This sequence will now be explained referring to the time-base assignment of Fig. 77. A compressed form of H_LV_L of the first channel is first fed to the expander 503 where it is expanded. Then, H_LV_H, H_HV_L, and H_HV_H are expanded. All the four expanded components are sent through a switch 812a to a mixer 556 where they are mixed to produce H_LV_L-H. H_LV_L-H is then fed back from the terminal 1 of a switch 765a through the input 2 of a switch 765 to the H_LV_L input of the mixer 556.

At the second timing, H_LV_H-H, H_HV_L-H, and H_HV_H of the D_2 signal shown in Fig. 77 are fed to the expander 503 where they are expanded before transferred through the switch 821a to the mixer 556. They are mixing by the mixer 556 to an HDTV signal which is fed through the terminal 2 of the switch 765a to the output unit 521 for further delivery.

The time-base assignment of data components for transmission, shown in Fig. 77, contributes to the simplest arrangement of the expander and mixer. Although Fig. 77 shows two, D_1 and D_2, signal levels, four-level transmission of a TV signal will be feasible using the additional of a D_3 signal and a super resolution HDTV signal.

Fig. 79 illustrates a time-base assignment of data components of a physical three-level, D_1, D_2, D_3, TV signal, in which data components of the same channel are so arranged as not to oeverlap with one another with time. Fig. 80 is a block diagram of a modified video decoder 423, similar to Fig. 78, in which a third input 521a is added. The time-base assignment of data components shown in Fig. 79 also contributes to the simple construction of the decoder.

The action of the modified decoder 432 is almost identical to that shown in Fig. 78 and associated with the time-base assignment shown in Fig. 77 and will no more be explained. It is also possible to multiplex data components on the D_1 signal as shown in Fig. 81. However, two data 821 and 822 are increased higher in the error correction capa-

bility than other data components 821a, 812b, 821c, thus staying at a higher signal level. More particularly, the data assignment for transmission is made in one physical level but two logic level relationship. Also, each data component of the second channel is inserted between two adjacent data components of the first channel so that serial processing can be executed at the receiver side and the same effects as of the time-base assignment shown in Fig. 79 will thus be obtained.

The time-base assignment of data components shown in Fig. 81 is based on the logic level mode and can also be carried in the physical level mode when the bit transmission rate of the two data components 821 and 822 is decreased to 1/2 or 1/3 thus to lower the error rate. The physical level arrangement is consisted of three different levels.

Fig. 82 is a block diagram of another modified video decoder 423 for decoding of the D_1 signal time-base arranged as shown in Fig. 81, which is simpler in construction than that shown in Fig. 80. Its action is identical to that of the decoder shown in Fig. 80 and will be no more explained.

As understood, the time-base assignment of data components shown in Fig. 81 also contributes to the simple arrangement of the expander and mixer. Also, four data components of the D_1 signal are fed at respective time slices to a mixer 556. Hence, the circuitry arrangement of the mixer 556 or a plurality of circuit blocks such as provided in the video mixer 548 of Fig. 32 may be arranged for changing the connection there between corresponding to each data component so that they become compatible in time division action and thus, minimized in circuitry construction.

Accordingly, the receiver can be minimized in the overall construction.

It would be understood that the fifth embodiment is not limited to ASK modulation and the other methods including PSK and QAM modulation, such as described in the first, second, and third embodiment, will be employed with equal success.

Also, FSK modulation will be eligible in any of the embodiments. For example, the signal points of a multiple-level FSK signal consisting of four frequency components f1,

f2, f3, f4 are divided into groups as shown in Fig. 58 and when the distance between any two groups are spaced from each other for ease of discrimination, the multi-level transmission of the FSK signal can be implemented, as illustrated in Fig. 83.

More particularly, it is assumed that the frequency group 841 of f1 and f2 is assigned $D_1=0$ and the group 842 of f3 and f4 is assigned $D_1=1$. if f1 and f3 represent 0 at D_2 and f2 and f4 represent 1 at D_2, two-bit data transmission, one bit at D_1 or D_2, will be possible as shown in Fig. 83. When the C/N rate is high, a combination of $D_1=0$ and $D_2=1$ is reconstructed at t = t3 and a combination of $D_1=1$ and $D_2=0$ at t=t4. When the C/N rate is low, $D_1=0$ only is reproduced at t=t3 and $D_1=1$ at t=t4. In this manner, the FSK signal can be transmitted in the multi-level arrangement. This multi-state FSK signal transmission is applicable to each of the third, fourth, and fifth embodiments.

The fifth embodiment may also be implemented in the form of a magnetic record/playback apparatus of which block diagram shown in Fig. 84 because its ASK mode action is

appropriate to magnetic record and playback operation.

As shown in Fig. 84, an input video signal to a magnetic record/playback apparatus 851 is divided and compressed by a video encoder 401. Then, a low frequency band component, e.g. $H_L V_L$, of the video signal is fed to a first data stream input 743 of an input unit 742 and a high frequency band component including $H_H V_H$ is fed to a second data stream input 744 of the same. The two components are further transferred to a modulator 749 of a modulator/demodulator unit 852. Those procedures are almost identical to those of the transmitter 774 of the fifth embodiment shown in Fig. 64. A modulated signal of the modulator 749 is fed through a record/playback circuit 853 to a magnetic head 854 for recording onto a magnetic tape 855. The recording procedure may be carried out by a physical multiple-level signal recording technique modified from a conventional digital multi-bit signal recording technique or a multi-level signal recording technique of phase modulation or phase amplitude modulation described in the first or third embodiment separately. Also, multi-level recording will be possible using

a multiple track of the magnetic tape or through varying the data transmission rate. Furthermore, logic multi-level recording will be possible by changing the error correction capability for data discrimination.

In playback action, a reproduced signal retrieved from the magnetic tape 855 by the magnetic head 854 and reconstructed by the record/playback circuit 853 is fed to a demodulator 760 of the modulator/demodulator unit 760. Then, the succeeding procedure is similar to that described in the first, third, or fourth embodiment. The first and second data streams D_1, D_2 reconstructed by the demodulator 760 are then converted by a video decoder 422 to a video signal. Thanking to the multi-level recording, a high resolution TV signal e.g. of HDTV will be reproduced when the C/N rate is high. If the C/N rate is low or a low-function magnetic player is used, a standard or lower NTSC TV signal only will be reproduced.

As understood, the magnetic record/playback apparatus of the present invention allows at least a low resolution component of a TV signal to be reconstructed in case that

the C/N rate is low or the error rate is high.

Embodiment 6

A sixth embodiment of the present invention will be described for execution of four-level video signal transmission. A combination of the four-level signal transmission and the four-level video data construction will create a four-level signal service area as shown in Fig. 91. The four-level service area is consisted of, from innermost, a first 890a, a second 890b, a third 890c, and a fourth signal receiving area 890d. The method of developing such a four-level service area will be explained in more detail.

The four-level arrangement can be implemented by using four physically different levels determined through modulation or four logic levels defined by data discrimination in the error correction capability. The former provides a large difference in the C/N rate between two adjacent levels and the C/N rate has to be increased to discriminate all the four levels from each other. The latter is based on the action of demodulation and a difference in the C/N rate between two adjacent levels should stay at minimum. Hence,

the four-level arrangement is best constructed using a combination of two physical levels and two logic levels. The division of a video signal into four signal levels will be explained.

Fig. 93 is a block diagram of a divider circuit 3 which comprises a video divider 895 and four compressors 405a, 405b, 405c, 405d. The video divider 895 contains three dividers 404a, 404b, 404c which are arranged identical to the divider circuit 404 of the first video encoder 401 shown in Fig. 30 and will be no more explained. An input video signal is divided by the dividers into four components, H_LV_L of low resolution data, H_HV_H of high resolution data, and H_LV_H and H_HV_L for medium resolution data. The resolution of H_LV_L is a half that of the original input signal.

The input video signal is first divided by the divider 404a into two, high and low, frequency band components, each component being divided into two, horizontal and vertical, segments. The intermediate between the high and low frequency ranges is a dividing point according to the embodiment. Hence, if the input video signal is an HDTV signal of

1000-line vertical resolution, H_LV_L has a vertical resolution of 500 lines and a horizontal resolution of a half value.

Each of two, horizontal and vertical, data of the low frequency component H_LV_L is further divided by the divider 404c into two frequency band segments. Hence, an H_LV_L segment output is 250 lines in the vertical resolution and 1/4 of the original horizontal resolution. This output of the divider 404c which is termed as an LL signal is then compressed by the compressor 405a to a D_{1-1} signal.

The other three higher frequency segments of H_LV_L are mixed by a mixer 772c to an LH signal which is then compressed by the compressor 405b to a D_{1-2} signal. The compressor 405b may be replaced with three compressors provided between the divider 404c and the mixer 772c.

H_LV_H, H_HV_L, and H_HV_H from the divider 404a are mixed by a mixer 772a to an H_HV_H-H signal. If the input signal is as high as 1000 lines in both horizontal and vertical resolution, H_HV_H-H has 500 to 1000 lines of a horizontal and a vertical resolution. H_HV_H-H is fed to the divider 404b

where it is divided again into four components.

Similarly, H_LV_L from the divider 404b has 500 to 750 lines of a horizontal and a vertical resolution and transferred as an HL signal to the compressor 405c. The other three components, H_LV_H, H_HV_L, and H_HV_H, from the divider 404b have 750 to 1000 lines of a horizontal and a vertical resolution and are mixed by a mixer 772b to an HH signal which is then compressed by the compressor 405d and delivered as a D_{202} signal. After compression, the HL signal is delivered as a D_{2-1} signal. As the result, LL or D_{1-1} carries a frequency data of 0 to 250 lines, LH or D_{1-2} carries a frequency data from more than 250 lines up to 500 lines, HL or D_{2-1} carries a frequency data of more than 500 lines up to 750 lines, and HH or D_{2-2} carries a frequency data of more than 750 lines to 1000 lines so that the divider circuit 3 can produce a four-level signal. Accordingly, when the divider circuit 3 of the transmitter 1 shown in Fig. 87 is replaced with the divider circuit of Fig. 93, the transmission of a four-level signal will be implemented.

The combination of multi-level data and multi-level

transmission allows a video signal to be at steps declined in the picture quality in proportion to the C/N rate during transmission., thus contributing to the enlargement of the TV broadcast service area. At the receiver side, the action of demodulation and reconstruction is identical to that of the second receiver of the second embodiment shown in Fig. 88 and will be no more explained. In particular, the mixer 37 is modified for video signal transmission rather than data communications and will now be explained in more detail.

As described in the second embodiment, a received signal after demodulated and error corrected, is fed as a set of four components D_{1-1}, D_{1-2}, D_{2-1}, D_{2-2} to the mixer 37 of the second receiver 33 of Fig. 88.

Fig. 97 is a block diagram of a modified mixer 33 in which D_{1-1}, D_{1-2}, D_{2-1}, D_{2-2} are expanded by their respective expanders 523a, 523b, 523c, 523d to an LL, an LH, an HL, and HH signal respectively which are equivalent to those described with Fig. 93. If the bandwidth of the input signal is 1, LL has a bandwidth of 1/4, LL+LH has a band-

width of 1/2, LL+LH+HL has a bandwidth of 3/4, and LL+LH+HL+HH has a bandwidth of 1. The LH signal is then divided by a divider 531a and mixed by a video mixer 548a with the LL signal. An output of the video mixer 548a is transferred to an H_LV_L terminal of a video mixer 548c. The video mixer 531a is identical to that of the second decoder 527 of Fig. 32 and will be no more explained. Also, the HH signal is divided by a divider 531b and fed to a video mixer 548b. At the video mixer 548b, the HH signal is mixed with the HL signal to an H_HV_H-H signal which is then divided by a divider 531c and sent to the video mixer 548c. At the video mixer 548c, H_HV_H-H is combined with the sum signal of LH and LL to a video output. The video output of the mixer 33 is then transferred to the output unit 36 of the second receiver shown in Fig. 88 where it is converted to a TV signal for delivery. If the original signal has 1050 lines of vertical resolution or is an HDTV signal of about 1000-line resolution, its four different signal level components can be intercepted in their respective signal receiving areas shown in Fig. 91.

The picture quality of the four different components will be described in more detail. The illustration of Fig. 92 represents a combination of Figs. 86 and 91. As apparent, when the C/N rate increases, the overall signal level or amount of data is increased from 862d to 862a by steps of four signal levels D_{1-1}, D_{1-2}, D_{2-1}, D_{2-2}.

Also, as shown in Fig. 95, the four different level components LL, LH, HL, and HH are accumulated in proportion to the C/N rate. More specifically, the quality of a reproduced picture will be increased as the distance from a transmitter antenna becomes small. When L=Ld, LL component is reproduced. When L=Lc, LL+LH signal is reproduced. When L=Lb, LL+LH+HL signal is reproduced. When L=La, LL+LH+HL+HH signal is reproduced. As the result, if the bandwidth of the original signal is 1, the picture quality is enhanced at 1/4 increments of bandwidth from 1/4 to 1 depending on the receiving area. If the original signal is an HDTV or 1000-line vertical resolution, a reproduced TV signal is 250, 500, 750, and 1000 lines in the resolution at their respective receiving areas. The picture quality will thus be

varied at steps depending on the level of a signal. Fig. 96 shows the signal propagation of a conventional digital HDTV signal transmission system, in which no signal reproduction will be possible when the C/N rate is less than Vo. Also, signal interception will hardly be guaranteed at signal interference regions, shadow regions, and other signal attenuating regions, denoted by the symbol x, of the service area. Fig. 97 shows the signal propagation of an HDTV signal transmission system of the present invention. As shown, the picture quality will be a full 1000-line grade at the distance La where C/N=a, a 750-line grade at the distance Lb where C/N=b, a 500-line grade at the distance Lc where C/N=c, and a 250-line grade at the distance Ld where C/N=d. Within the distance La, there are some unfavorable regions where the CN rate drops sharply and no HDTV quality picture will be reproduced. As understood, a lower picture quality signal can however be intercepted and reproduced according to the multi-level signal transmission system of the present invention. For example, the picture quality will be a 750-line grade at the point B in a building shadow

n-value first data stream by the demodulator 25, the first data stream and second data stream in the second receiver 33, and the first data stream, second data stream and third data stream in the third receiver 43, therefore, a compatible and extendable signal transmission system is obtained which is capable of demodulating n-value data even in the receiver having the capacity of demodulating the n-value where $n < m$ from the multiple modulated wave modulated from the maximum m-value data.

By transmitting the NTSC signal as first data stream, and the differential signal of HDTV and NTSC as second data stream, NTSC broadcast and HDTV broadcast are compatible, and digital broadcasting of high extendability of information quantity is realized, which are notable effects.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view of the entire arrangement of a signal transmission system showing a first embodiment of the present invention;

Fig. 2 is a block diagram of a transmitter of the first

embodiment;

Fig. 3 is a vector diagram showing a transmission signal of the first embodiment;

Fig. 4 is a vector diagram showing a transmission signal of the first embodiment;

Fig. 5 is a view showing an assignment of binary codes to signal points according to the first embodiment;

Fig. 6 is a view showing an assignment of binary codes to signal point groups according to the first embodiment;

Fig. 7 is a view showing an assignment of binary codes to signal points in each signal point group according to the first embodiment;

Fig. 8 is a view showing another assignment of binary codes to signal point groups and their signal points according to the first embodiment;

Fig. 9 is a view showing threshold values of the signal point groups according to the first embodiment;

Fig. 10 is a vector diagram of a modified 16 QAM signal of the first embodiment;

Fig. 11 is a graphic diagram showing the relation

area, a 250-line grade at the point D in a running train, a 750-line grade at the point F in a ghost developing area, a 250-line grade at the point G in a running car, and a 250-line grade at the point L in a neighbor signal interference area. As set forth above, the signal transmission system of the present invention allows a TV signal to be successfully received at a grade in the area where the conventional system is poorly qualified, thus increasing its service area. Fig. 98 shows an example of simultaneous broadcasting of four different TV programs, in which three quality programs C, B, A are transmitted on their respective channels D_{1-2}, D_{2-1}, D_{2-2} while a program D identical to that of a local analog TV station is propagated on the D_{1-1} channel. Accordingly, while the program D is kept available at simulcast service, the other three programs can also be distributed on air for offering a multiple program broadcast service.

The transmission method of the invention is to enhance the frequency utilization efficiency, but the power utilization efficiency is considerably lowered in certain receiv-

ers. It is, therefore, not applicable to all transmission systems. For example, in the satellite communication system for specific users, the most economical way is to change to the apparatus having the maximum frequency and power utilization efficiency available at the time depending on the technical innovation, and it is not always required to employ this invention.

In the case of, on the other hand, satellite communication appliances and broadcasting system for household use or small companies, the technique of the invention is required. It is because the satellite broadcasting standard is required to persist more than scores of years. In this period of scores of years, the standard, or the frequency band is not changed, but the transmission electric power of the satellite will be outstandingly improved. In this case, scores of years later, the broadcasting station is responsible for the requirement that the programs should be received even by the existing appliances manufactured at the end of the twentieth century.

From this viewpoint, the invention emphasizes the

frequency efficiency, rather than the power efficiency, and the electric power of the transmitter is not increased so much by setting several reception sensitivities at the receiver side, and therefore it is possible to transmit by the present satellite, and compatible plural pieces of information can be transmitted simultaneously. If the transmission electric power is increased, since it is possible to transmit in the same standard, the future extendability and compatibility with the existing appliances are guaranteed. Hence, as described herein, the invention brings about notable effects when applied in the future broadcasting standards or the like.

Effects of the Invention

Thus, according to the invention, in the transmission apparatus for transmitting data comprising a signal input unit, a modulation unit for modulating plural carriers differing in phase and generating m signal points on a signal vector diagram, and a transmission unit for transmitting a modulated signal, a first data stream and a second

data stream of n values are entered, the signal is divided into n signal point groups to assign to the data of the first data stream of the signal point groups, while the data of the second data group are assigned to the signal points in the signal point groups, and the signal is transmitted by a transmitter which transmits a signal, and the signal is divided into n signal point groups in a reception apparatus comprising an input unit of the transmission signal, a demodulator for demodulating the QAM modulated wave of p signal points on the signal space diagram, and an output unit, and the first data stream of n values of signal point groups are modulated by corresponding, the data of the second data stream of p/n values are demodulated and reproduced to p/n signal points in the signal point groups, and the data is transmitted by using the reception apparatus, and hence, by the modulator 4 of the transmitter 1, for example, the n-value first data stream, second data stream and third data stream are assigned to the signal point groups, and modified m-value QAM modulation signal is transmitted, and in the first receiver 23, by demodulating the

between antenna radius r_2 and transmission energy ratio n according to the first embodiment;

Fig. 12 is a view showing the signal points of a modified 64 QAM signal of the first embodiment;

Fig. 13 is a graphic diagram showing the relation between antenna radius r_3 and the transmission energy ratio n according to the first embodiment;

Fig. 14 is a vector diagram showing signal point groups and their signal points of the modified 64 QAM signal of the first embodiment;

Fig. 15 is an explanatory view showing the relation between A_1 and A_2 of the modified 64 QAM signal of the first embodiment;

Fig. 16 is a graphic diagram showing the relation between antenna radius r_2, r_3 and transmission energy ratio n_{16}, n_{64} respectively according to the first embodiment;

Fig. 17 is a block diagram of a digital transmitter of the first embodiment;

Fig. 18 is a signal space diagram of a 4 PSK modulated signal of the first embodiment;

Fig. 19 is a block diagram of a first receiver of the first embodiment;

Fig. 20 is a signal space diagram of a 4 PSK modulated signal of the first embodiment;

Fig. 21 is a block diagram of a second receiver of the first embodiment;

Fig. 22 is a vector diagram of a modified 16 QAM signal of the first embodiment;

Fig. 23 is a vector diagram of a modified 64 QAM signal of the first embodiment;

Fig. 24 is a flow chart showing an action of the first embodiment;

Figs. 25-a and 25-b are vector diagrams showing an 8 and a 16 QAM signal of the first embodiment respectively;

Fig. 26 is a block diagram of a third receiver of the first embodiment;

Fig. 27 is a view showing signal points of the modified 64 QAM signal of the first embodiment;

Fig. 28 is a flow chart showing another action of the first embodiment;

Fig. 29 is a schematic view of the entire arrangement of a signal transmission system showing a third embodiment of the present invention;

Fig. 30 is a block diagram of a first video encoder of the third embodiment;

Fig. 31 is a block diagram of a first video decoder of the third embodiment;

Fig. 32 is a block diagram of a second video decoder of the third embodiment;

Fig. 33 is a block diagram of a third video decoder of the third embodiment;

Fig. 34 is an explanatory view showing a time multiplexing of D_1, D_2 and D_3 signals according to the third embodiment;

Fig. 35 is an explanatory view showing another time multiplexing of the D_1, D_2, and D_3 signals according to the third embodiment;

Fig. 36 is an explanatory view showing a further time multiplexing of the D_1, D_2, and D_3 signals according to the third embodiment;

Fig. 37 is a schematic view of the entire arrangement of a signal transmission system showing a fourth embodiment of the present invention;

Fig. 38 is a vector diagram of a modified 16 QAM signal of the third embodiment;

Fig. 39 is a vector diagram of the modified 16 QAM signal of the third embodiment;

Fig. 40 is a vector diagram of a modified 64 QAM signal of the third embodiment;

Fig. 41 is a diagram of assignment of data components on a time base according to the third embodiment;

Fig. 42 is a diagram of assignment of data components on a time base in TDMA action according to the third embodiment;

Fig. 43 is a block diagram of a carrier reproducing circuit of the third embodiment;

Fig. 44 is a diagram showing the principle of carrier wave reproduction according to the third embodiment;

Fig. 45 is a block diagram of a carrier reproducing circuit for reverse modulation of the third embodiment;

Fig. 46 is a diagram showing an assignment of signal points of the 16 QAM signal of the third embodiment;

Fig. 47 is a diagram showing an assignment of signal points of the 64 QAM signal of the third embodiment;

Fig. 48 is a block diagram of a carrier reproducing circuit for 16x multiplication of the third embodiment;

Fig. 49 is an explanatory view showing a time multiplexing of D_{V1}, D_{H1}, D_{V2}, D_{H2}, D_{V3}, and D_{H3} signals according to the third embodiment;

Fig. 50 is an explanatory view showing a TDMA time multiplexing of the D_{V1}, D_{H1}, D_{V2}, D_{H2}, D_{V3}, and D_{H3} signals according to the third embodiment;

Fig. 51 is an explanatory view showing another TDMA time multiplexing of the D_{V1}, D_{H1}, D_{V2}, D_{H2}, D_{V3}, and D_{H3} signals according to the third embodiment;

Fig. 52 is a diagram showing a signal interference region in a known transmission method according to the fourth embodiment;

Fig. 53 is a diagram showing signal interference regions in a multi-level signal transmission method according

to the fourth embodiment;

Fig. 54 is a diagram showing signal attenuating regions in the known transmission method according to the fourth embodiment;

Fig. 55 is a diagram showing signal attenuating regions in the multi-level signal transmission method according to the fourth embodiment;

Fig. 56 is a diagram showing a signal interference region between two digital TV station according to the fourth embodiment;

Fig. 57 is a diagram showing an assignment of signal points of a modified 4 ASK signal of the fifth embodiment;

Fig. 58 is a diagram showing another assignment of signal points of the modified 4 ASK signal of the fifth embodiment;

Figs. 59-a and 59-b are diagrams showing assignment of signal points of the modified 4 ASK signal of the fifth embodiment;

Fig. 60 is a diagram showing another assignment of signal points of the modified 4 ASK signal of the fifth

embodiment when the C/N rate is low;

Fig. 61 is a block diagram of a transmitter of the fifth embodiment;

Figs. 62-a and 62-b are diagrams showing frequency distribution profiles of an ASK modulated signal of the fifth embodiment;

Fig. 63 is a block diagram of a receiver of the fifth embodiment;

Fig. 64 is a block diagram of a video signal transmitter of the fifth embodiment;

Fig. 65 is a block diagram of a TV receiver of the fifth embodiment;

Fig. 66 is a block diagram of another TV receiver of the fifth embodiment;

Fig. 67 is a block diagram of a satellite-to-ground TV receiver of the fifth embodiment;

Fig. 68 is a diagram showing an assignment of signal points of an 8 ASK signal of the fifth embodiment;

Fig. 69 is a block diagram of a video encoder of the fifth embodiment;

Fig. 70 is a block diagram of a video encoder of the fifth embodiment containing one divider circuit;

Fig. 71 is a block diagram of a video decoder of the fifth embodiment;

Fig. 72 is a block diagram of a video decoder of the fifth embodiment containing one mixer circuit;

Fig. 73 is a diagram showing a time assignment of data components of a transmission signal according to the fifth embodiment;

Fig. 74-a is a block diagram of a video decoder of the fifth embodiment;

Fig. 74-b is a diagram showing another time assignment of data components of the transmission signal according to the fifth embodiment;

Fig. 75 is a diagram showing a time assignment of data components of a transmission signal according to the fifth embodiment;

Fig. 76 is a diagram showing a time assignment of data components of a transmission signal according to the fifth embodiment;

Fig. 77 is a diagram showing a time assignment of data components of a transmission signal according to the fifth embodiment;

Fig. 78 is a block diagram of a video decoder of the fifth embodiment;

Fig. 79 is a diagram showing a time assignment of data components of a three-level transmission signal according to the fifth embodiment;

Fig. 80 is a block diagram of another video decoder of the fifth embodiment;

Fig. 81 is a diagram showing a time assignment of data components of a transmission signal according to the fifth embodiment;

Fig. 82 is a block diagram of a video decoder for D_1 signal of the fifth embodiment;

Fig. 83 is a graphic diagram showing the relation between frequency and time of a frequency modulated signal according to the fifth embodiment;

Fig. 84 is a block diagram of a magnetic record/playback apparatus of the fifth embodiment;

Fig. 85 is a graphic diagram showing the relation between C/N and level according to the second embodiment;

Fig. 86 is a graphic diagram showing the relation between C/N and transmission distance according to the second embodiment;

Fig. 87 is a block diagram of a transmitter of the second embodiment;

Fig. 88 is a block diagram of a receiver of the second embodiment;

Fig. 89 is a graphic diagram showing the relation between C/N and error rate according to the second embodiment;

Fig. 90 is a diagram showing signal attenuating regions in the three-level transmission of the fifth embodiment;

Fig. 91 is a diagram showing signal attenuating regions in the four-level transmission of a six embodiment;

Fig. 92 is a diagram showing the four-level transmission of the sixth embodiment;

Fig. 93 is a block diagram of a divider of the sixth embodiment;

Fig. 94 is a block diagram of a mixer of the six embodiment;

Fig. 95 is a diagram showing another four-level transmission of the sixth embodiment;

Fig. 96 is a view of signal propagation of a known digital TV broadcast system;

Fig. 97 is a view of signal propagation of a digital TV broadcast system according to the sixth embodiment;

Fig. 98 is a diagram showing a four-level transmission of the sixth embodiment;

Reference Numerals

1	Transmitter
4	Modulator
6	Antenna
6a	Terrestrial antenna
10	Satellite
12	Repeater
23	First receiver
25	Demodulator

33 Second receiver

35 Demodulator

43 Third receiver

51 Digital transmitter

85 Signal point

91 First division signal point group

401 First image encoder

07.12.92

[Document name] Abstract of the Disclosure

[Abstract]

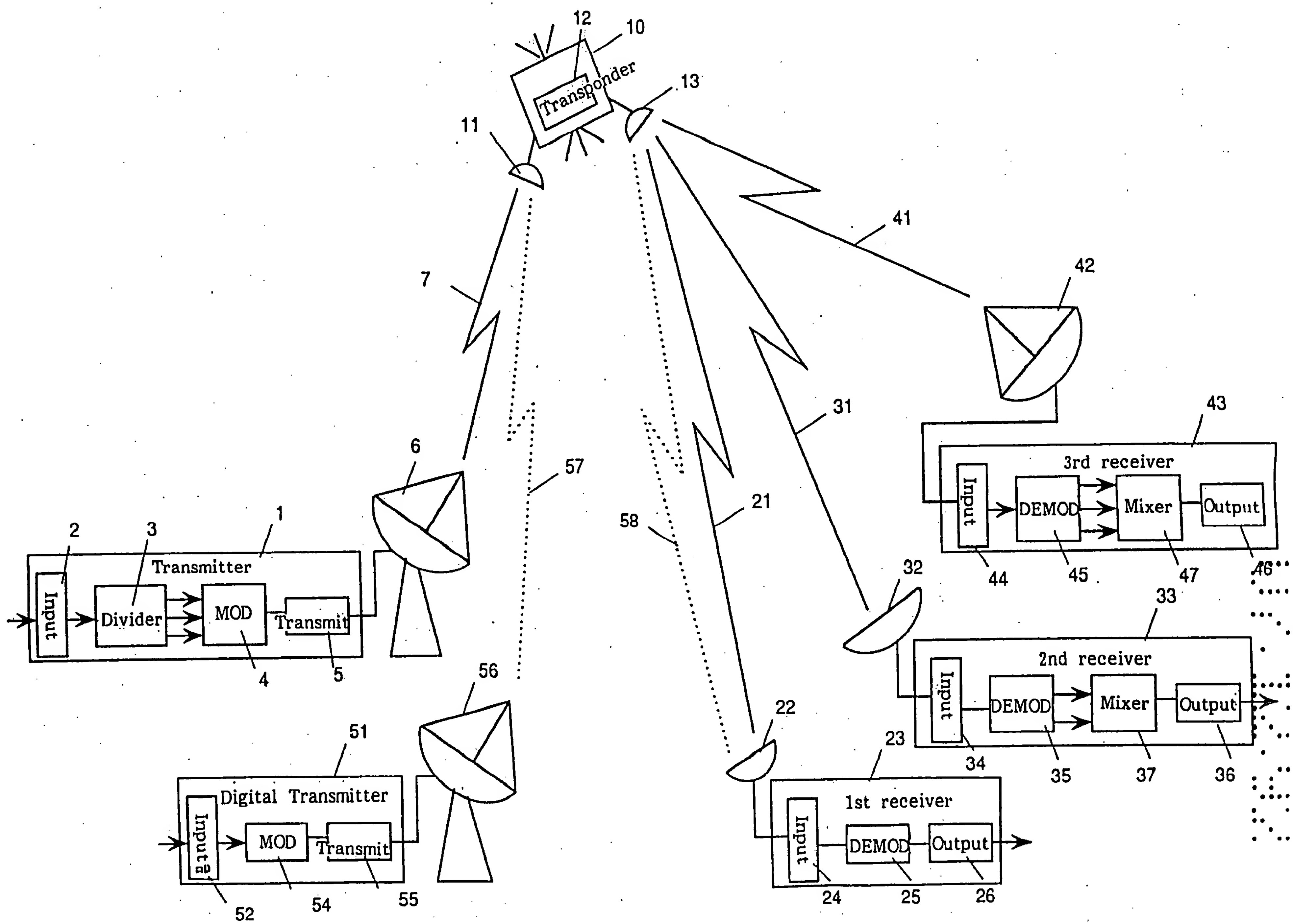
[Purpose] To present a signal transmission and reception system capable of transmitting more information in a same frequency band by solving the problem that the transmission information quantity cannot be increased when the frequency band is limited in a signal transmission system for transmitting digital signals.

[Constitution] In a transmitter 1, by a modulator 4 for performing QAM modulation of m values, a first data stream of n values, a second data stream of p values, and a third data stream are assigned with data of n values of the first data stream in the signal point group grouping signal points on the signal space diagram, and a QAM modulation signal of modified m values is transmitted. In a first receiver 23, by a demodulator 25, the first data stream is demodulated, while the first data stream and second data stream are demodulated in a second receiver 23, and the first data stream, second data stream, and third data stream in a third receiver 43, thereby obtaining a signal transmis-

sion system capable of demodulating data of the first data stream of n values even in a receiver having a demodulation capacity of n values where n < m when receiving a modified multiple value modulation wave of m values.

[Selected drawing] Fig. 1.

FIG.1



Transponder
Transmitter
Input
Divider
MOD
Transmit
Digital Transmitter
Input
MOD
Transmit
1st receiver
Input
DEMOD
Output
2nd receiver
Input
DEMOD
Mixer
Output
3rd receiver
Input
DEMOD
Mixer
Output
1
2
3
4
5
6
7
10
11
12
13
21
22
23
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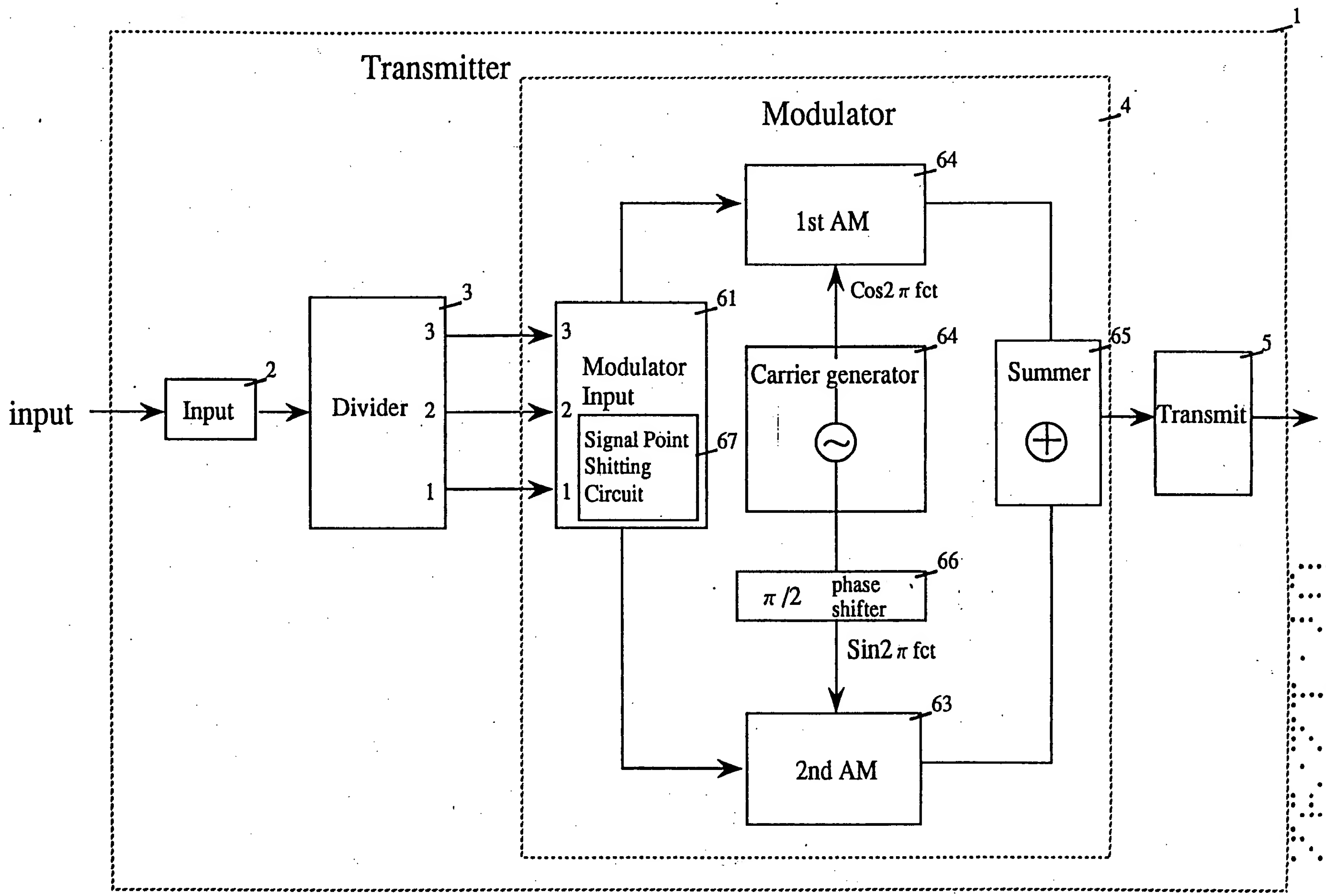
FIG.2



Transmitter
1
Modulator
4
input
Input
2
Divider
3
3
2
1
Modulator Input
61
3
2
1
Signal Point Shitting Circuit
67
1st AM
64
Cos2 π fct
Carrier generator
64
π /2 phase shifter
66
Sin2 π fct
2nd AM
63
Summer
65
Transmit
5

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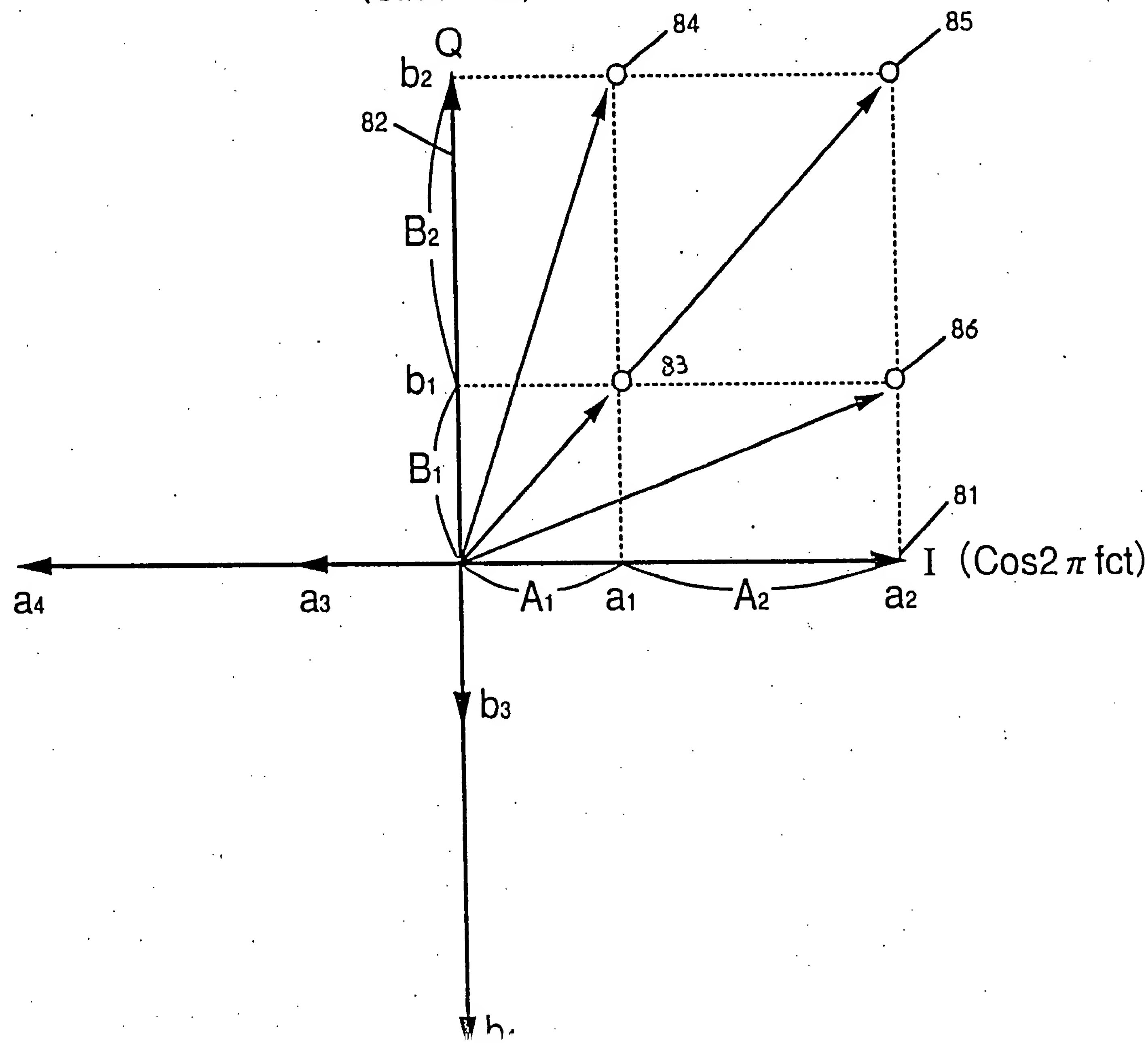
FIG. 3



(Sin2 π fct)
Q
84
85
b2
82
B2
86
b1
83
B1
81
I (Cos2 π fct)
a4
a3
A1
a1
A2
a2
b3
b4

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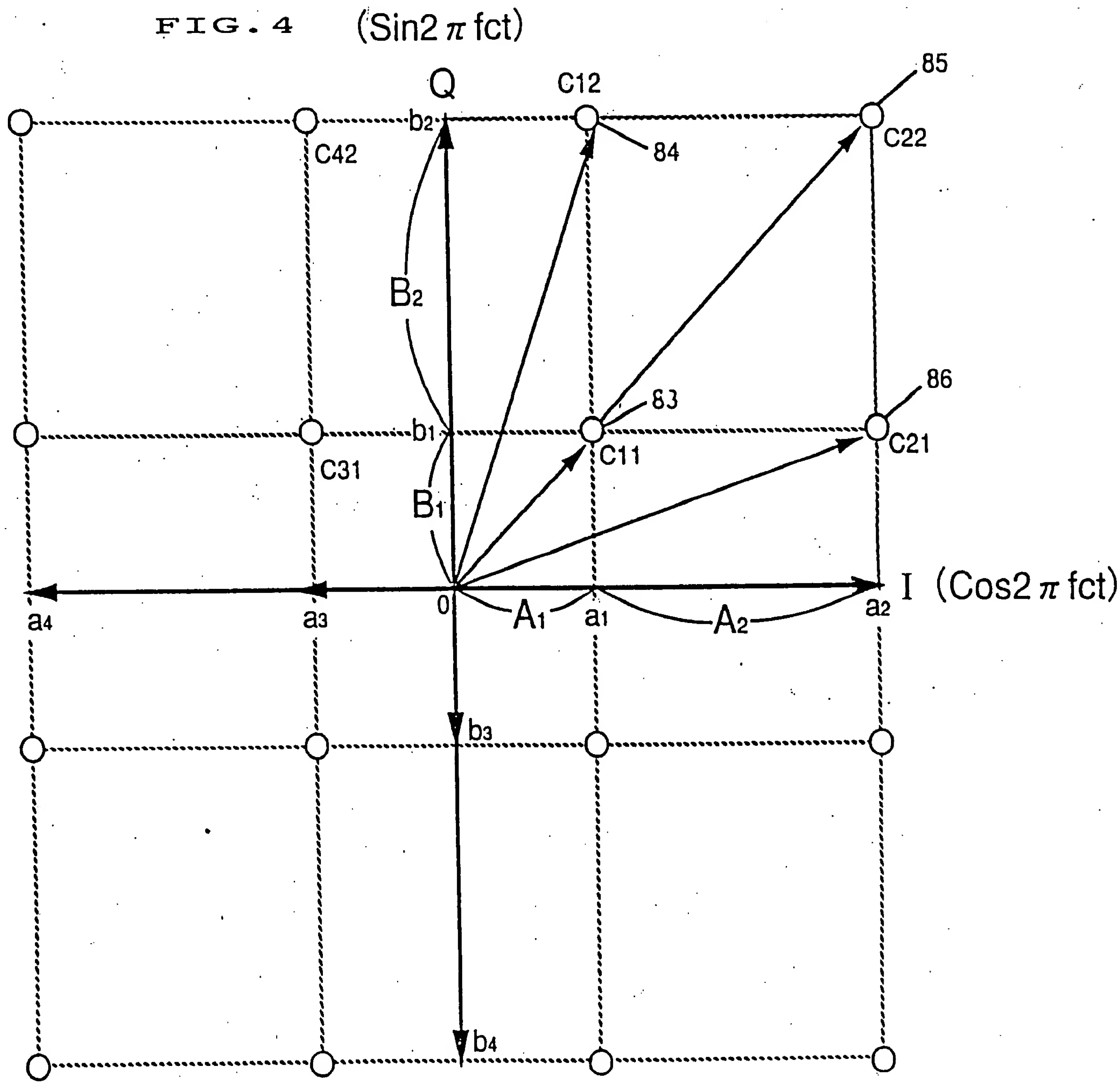
FIG. 4



(Sin2 π fct)
Q
b2
C12
85
C22
84
C42
B2
86
83
b1
C11
C21
C31
B1
I (Cos2 π fct)
0
A1
a1
A2
a2
a4
a3
b3
b4

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FIG. 5

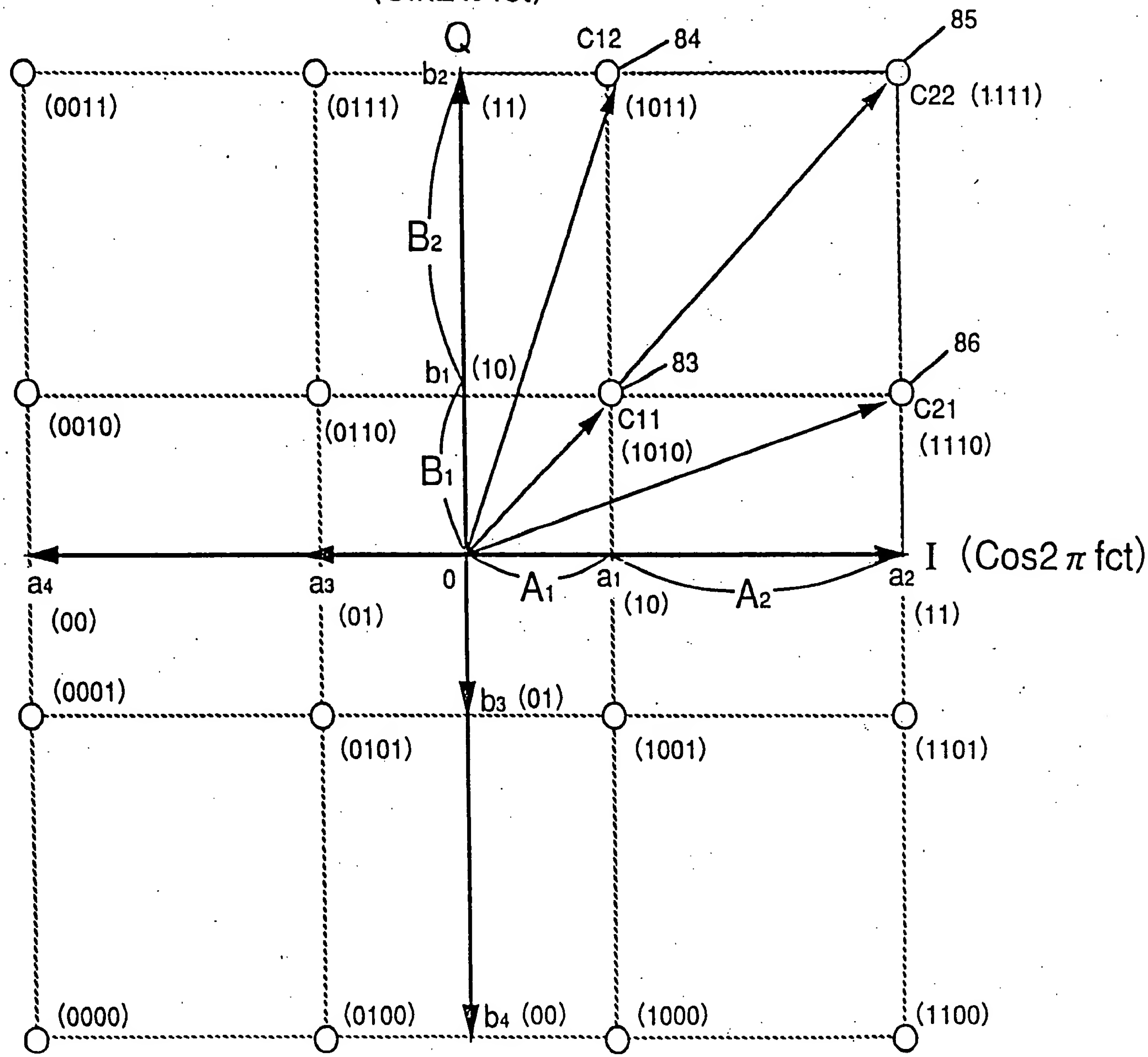
(Sin2π fct)
Q
I (Cos2π fct)
C12
84
85
C22 (1111)
b2
(0011)
(0111)
(11)
(1011)
B2
86
83
b1
(10)
C11
(1010)
C21
(1110)
(0010)
(0110)
B1
0
A1
a1
A2
a2
a3
a4
(00)
(01)
(10)
(11)
(0001)
b3 (01)
(0101)
(1001)
(1101)
(0000)
(0100)
b4 (00)
(1000)
(1100)

FIG.6

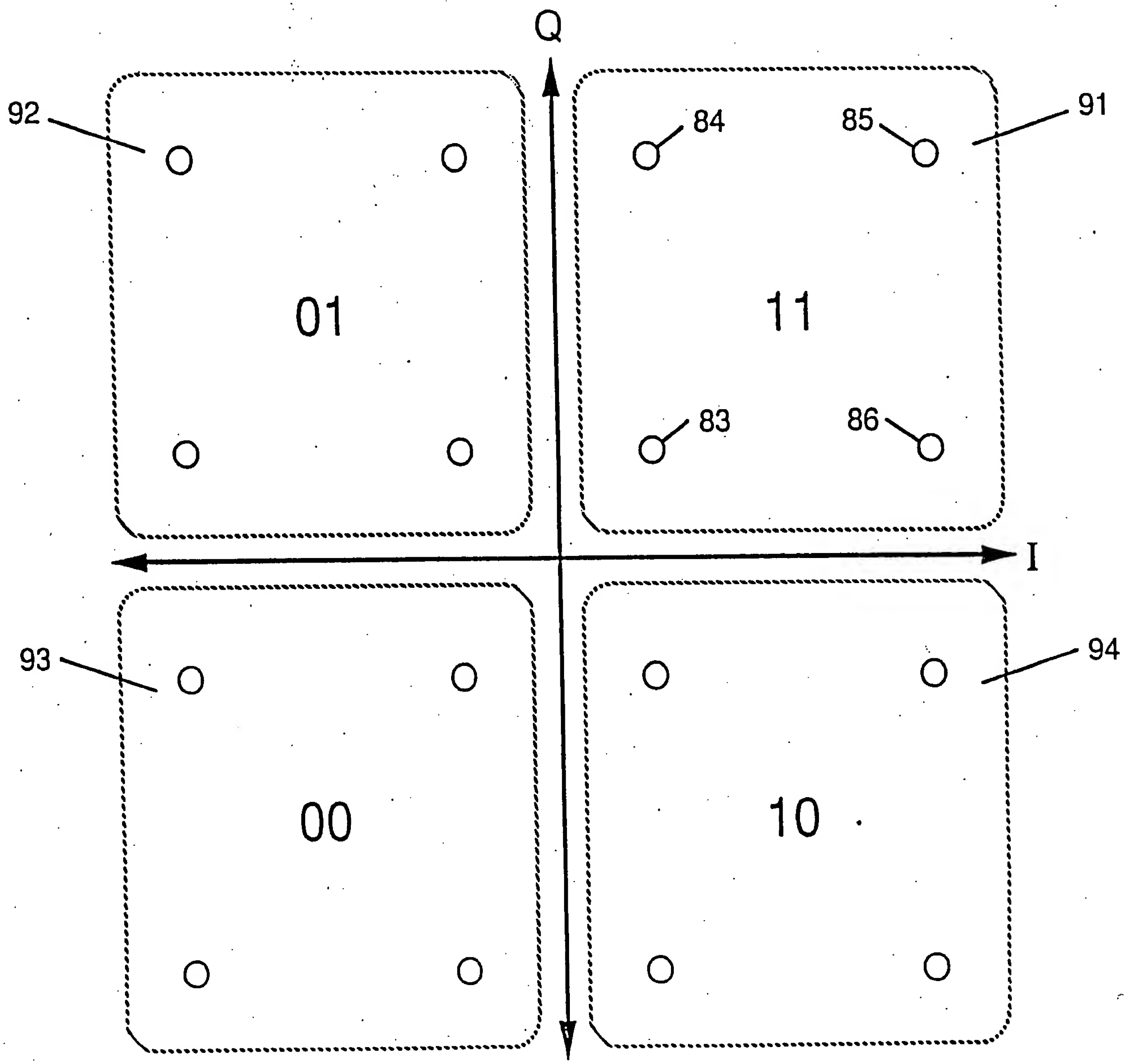

FIG.7

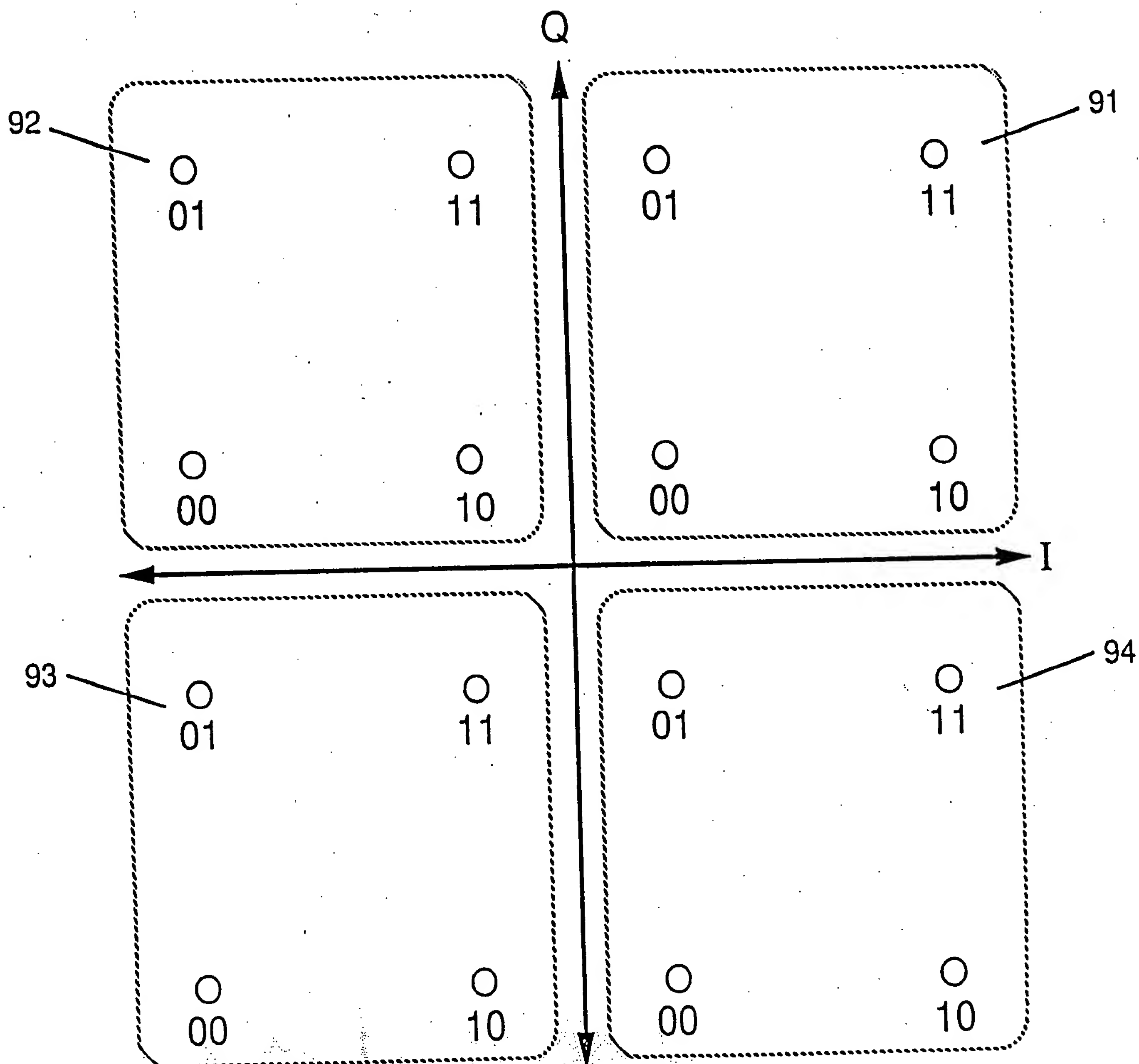

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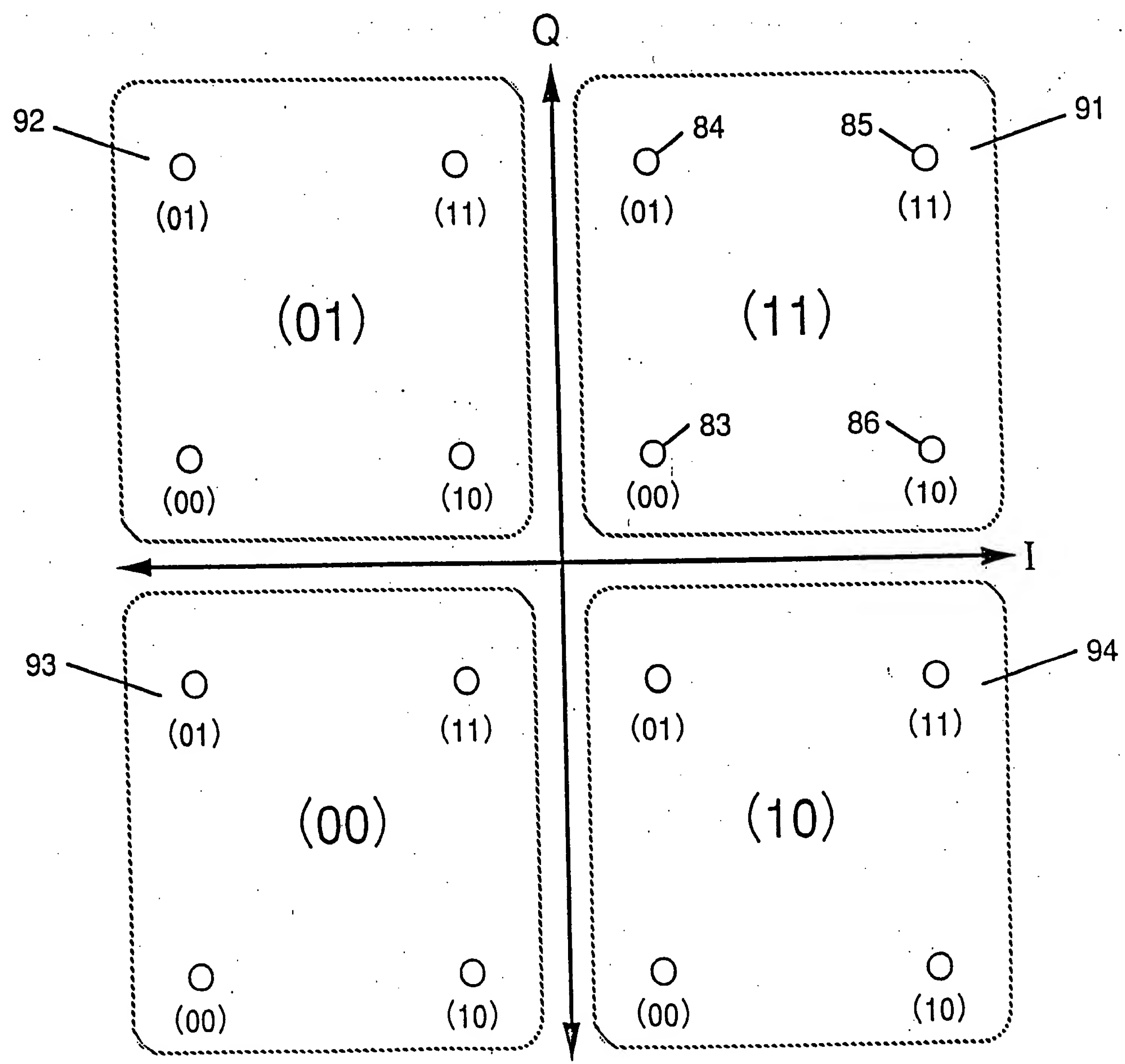
FIG. 8



Q
I
92
(01)
(11)
(01)
(00)
(10)
84
85
91
(01)
(11)
(11)
83
86
(00)
(10)
93
(01)
(11)
(00)
(00)
(10)
94
(01)
(11)
(10)
(00)
(10)

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FIG. 9

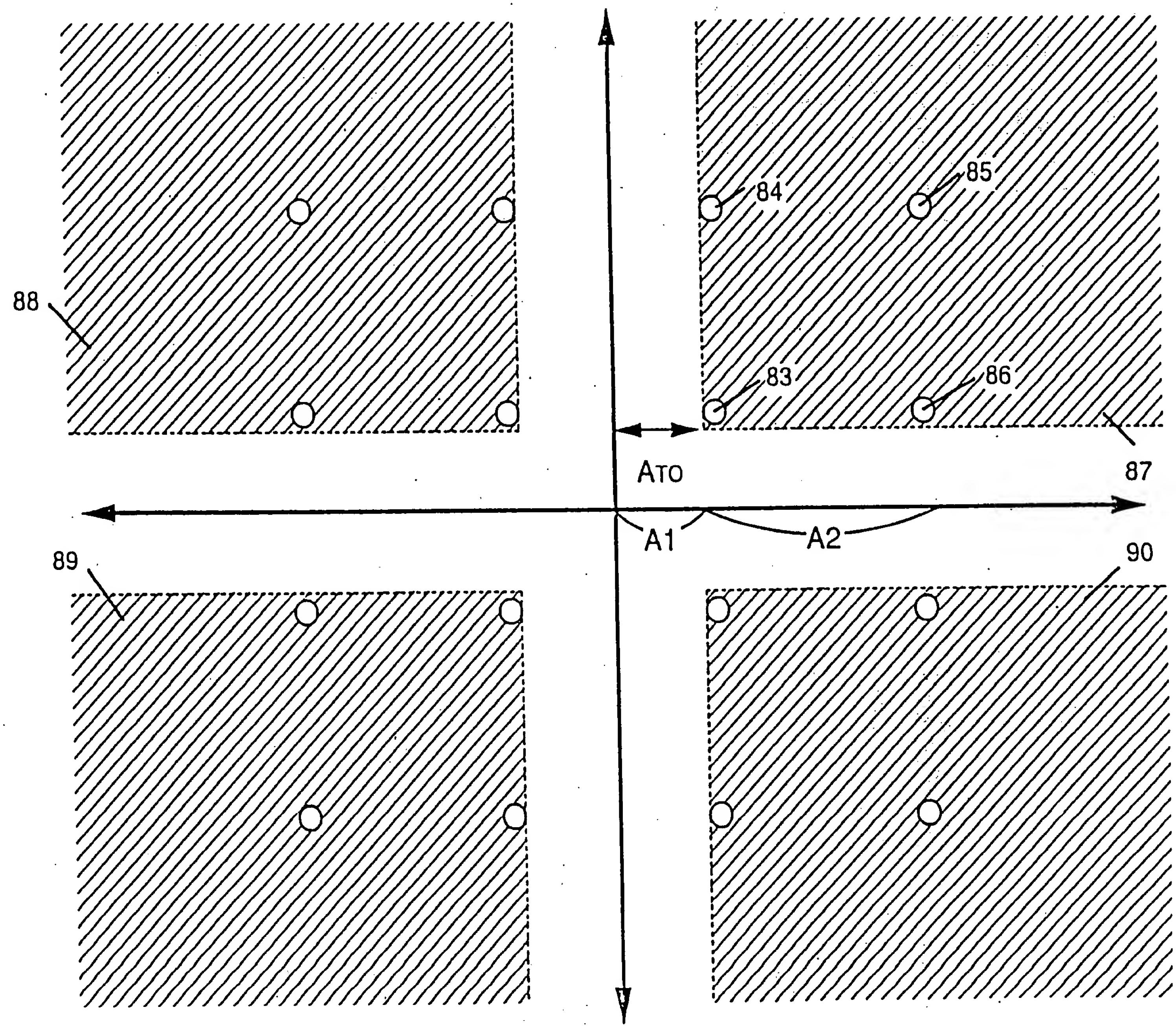

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FIG. 10

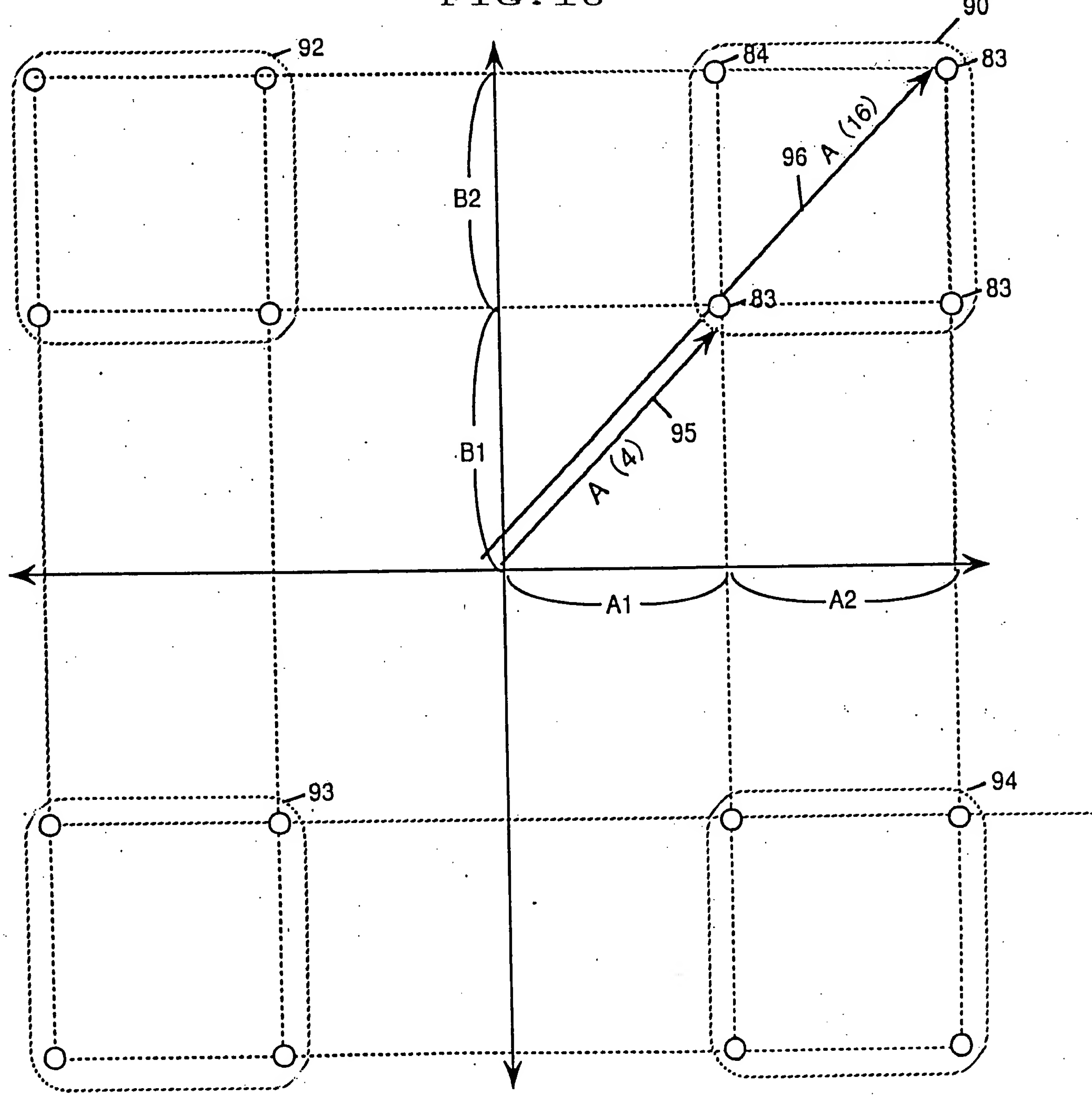

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FIG.11

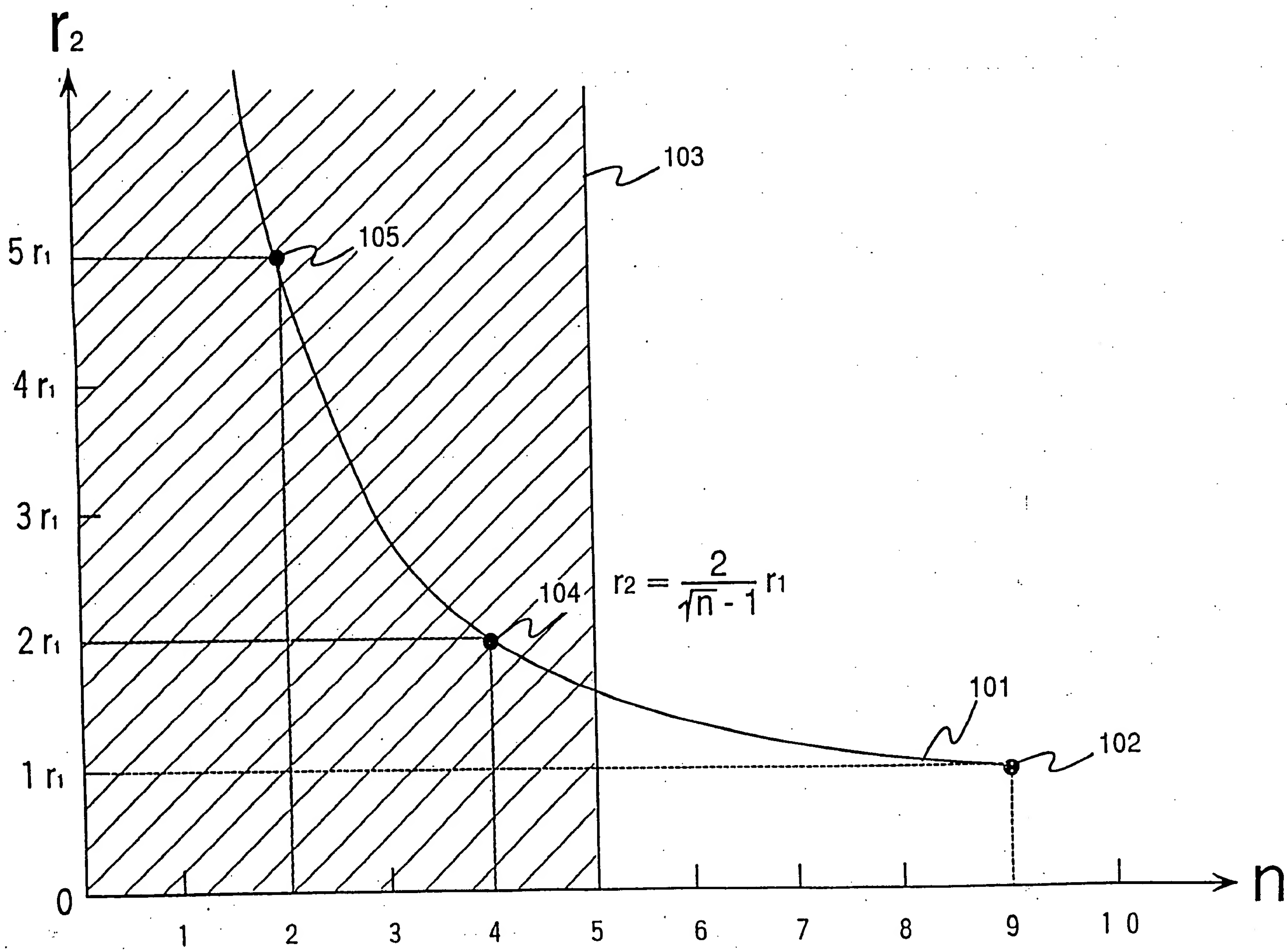

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FIG.12

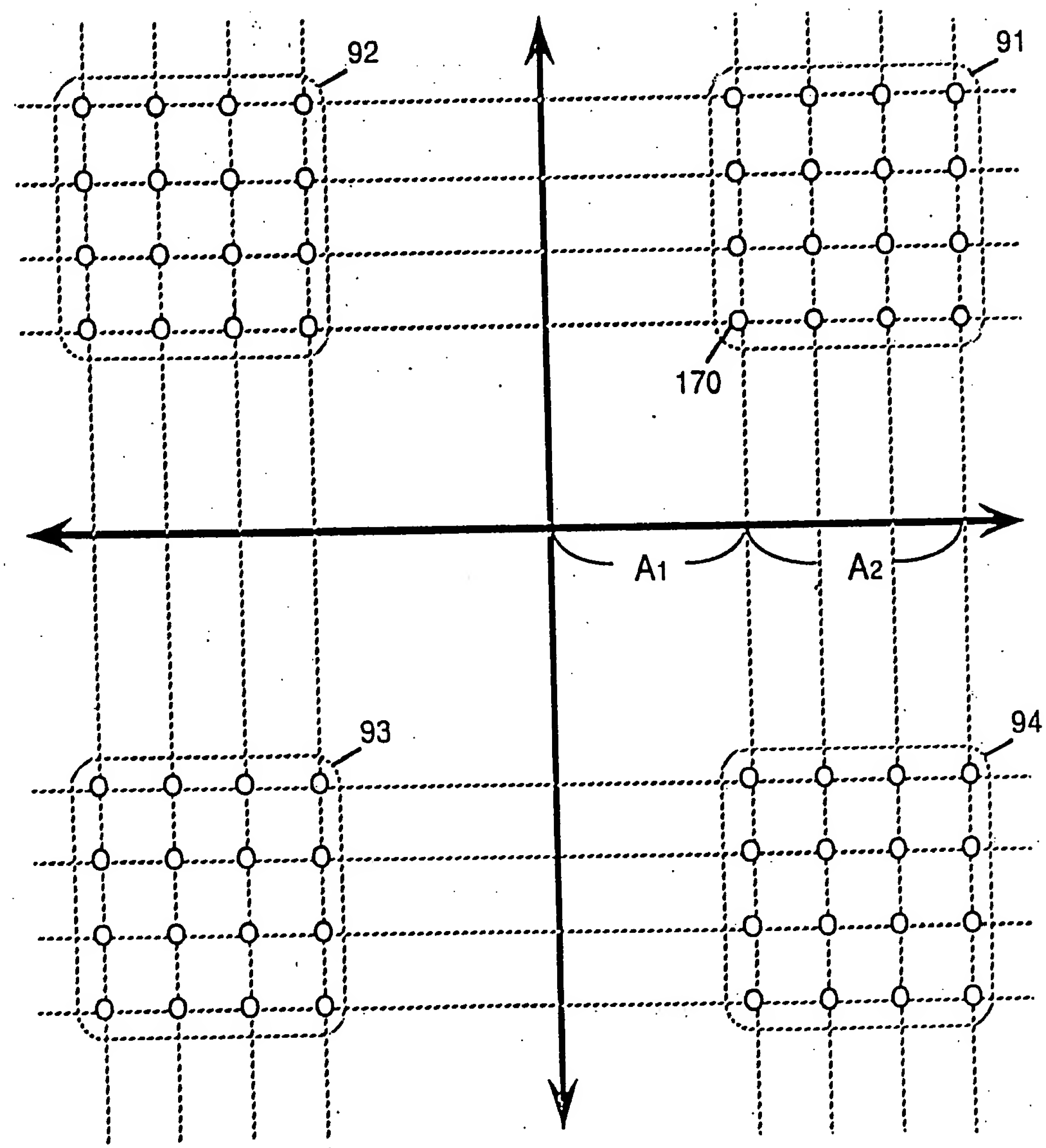

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FIG.13

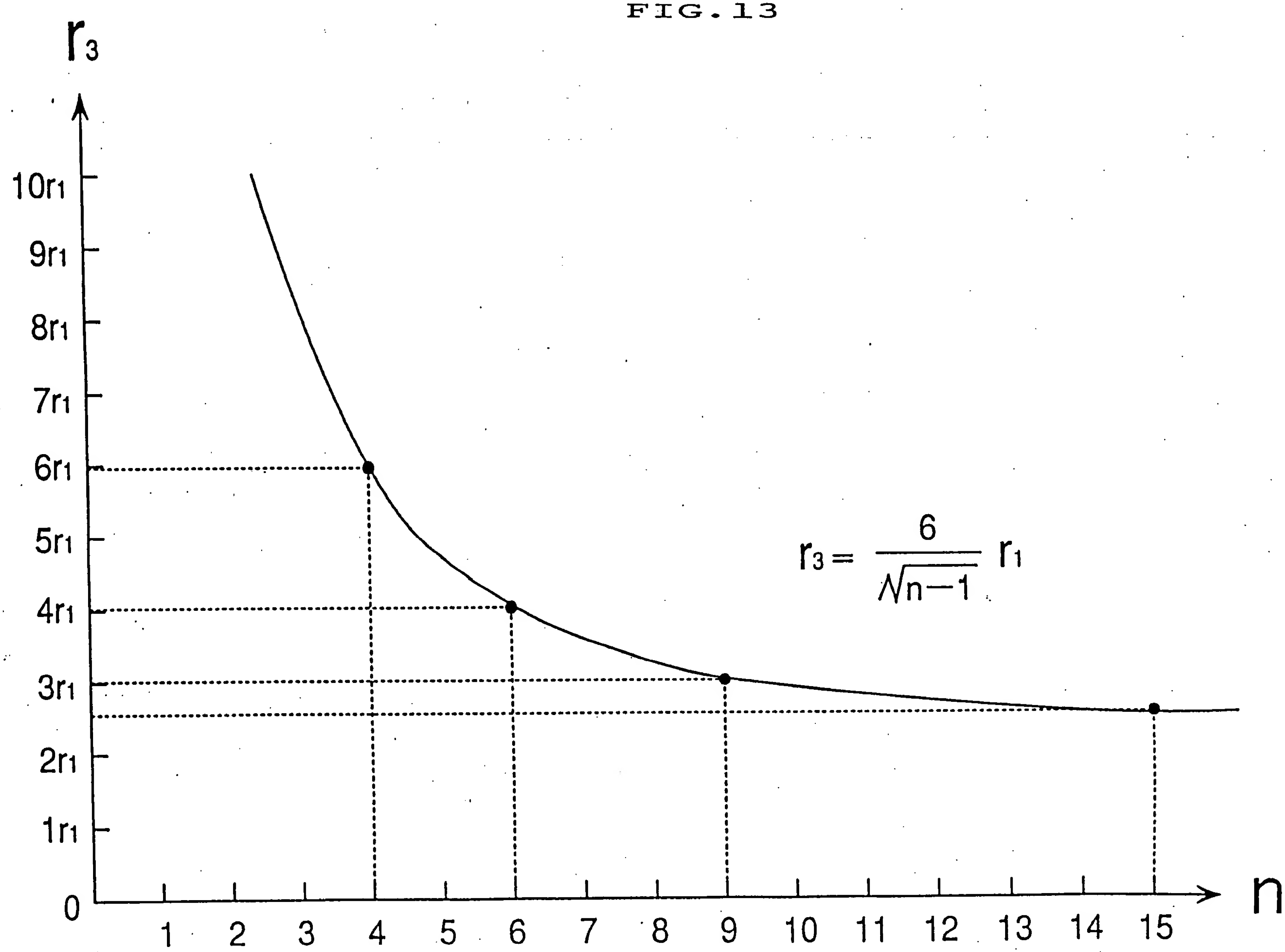

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FIG. 14

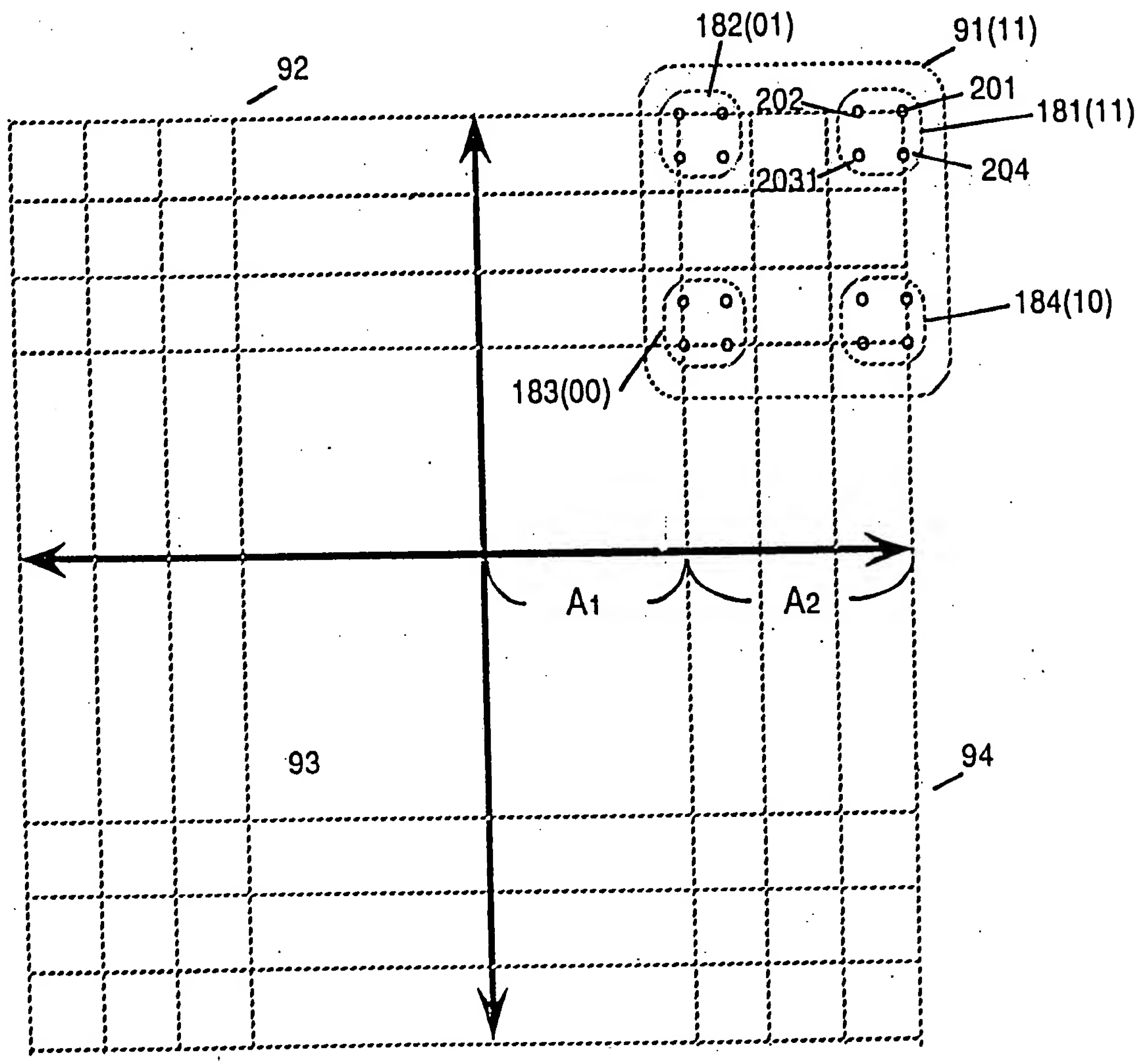

FIG.15

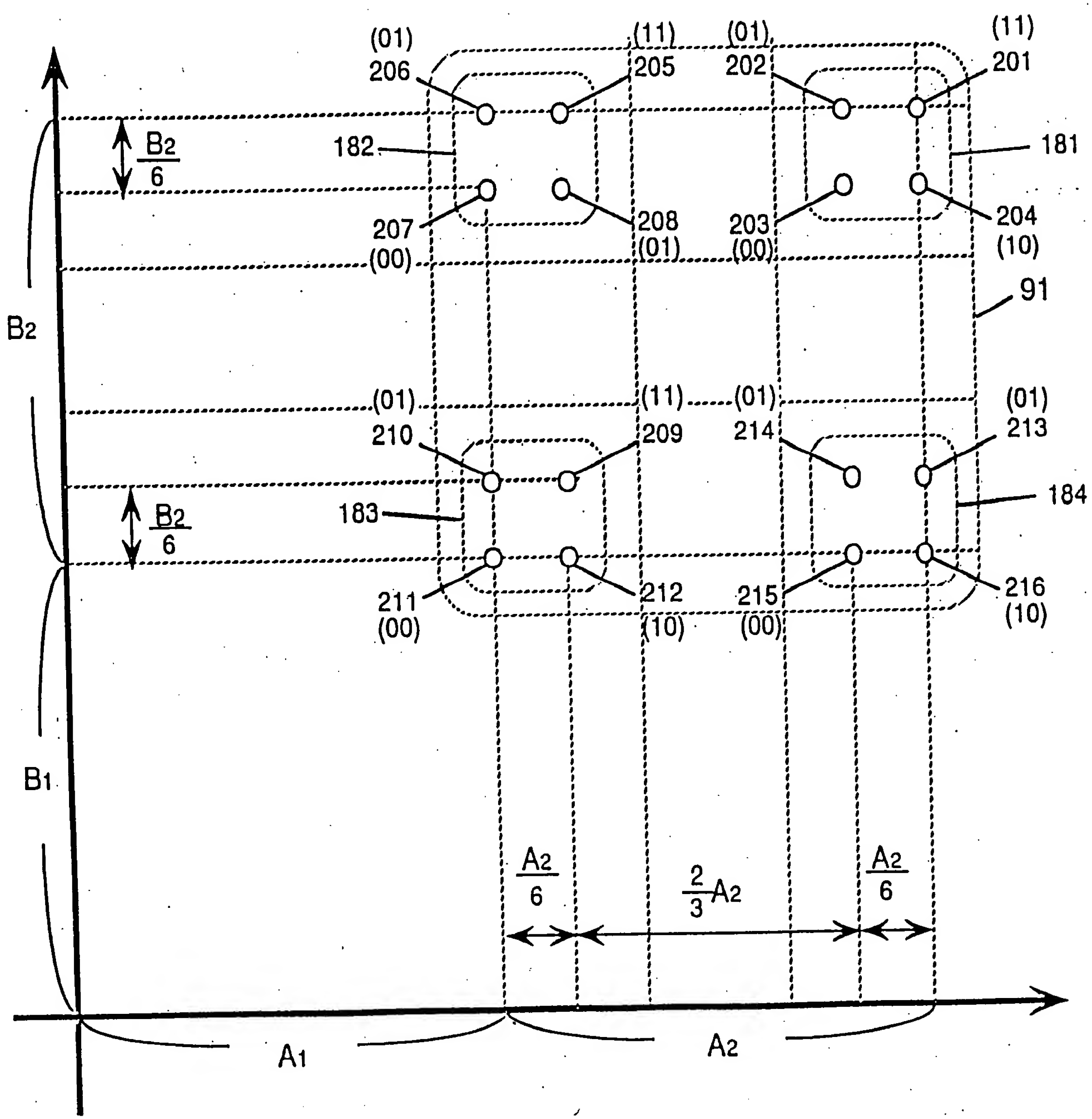

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FIG.16

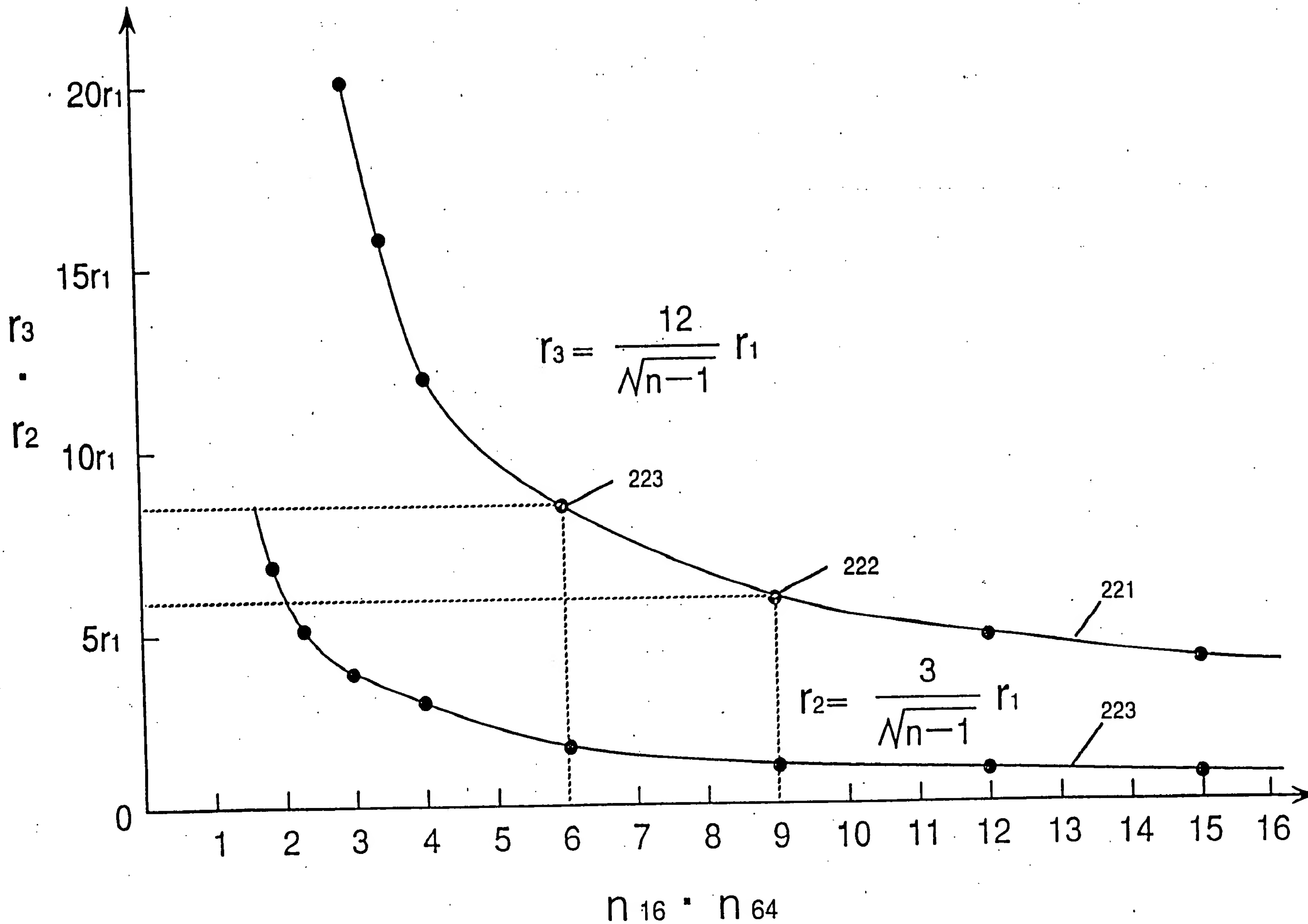

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FIG.17

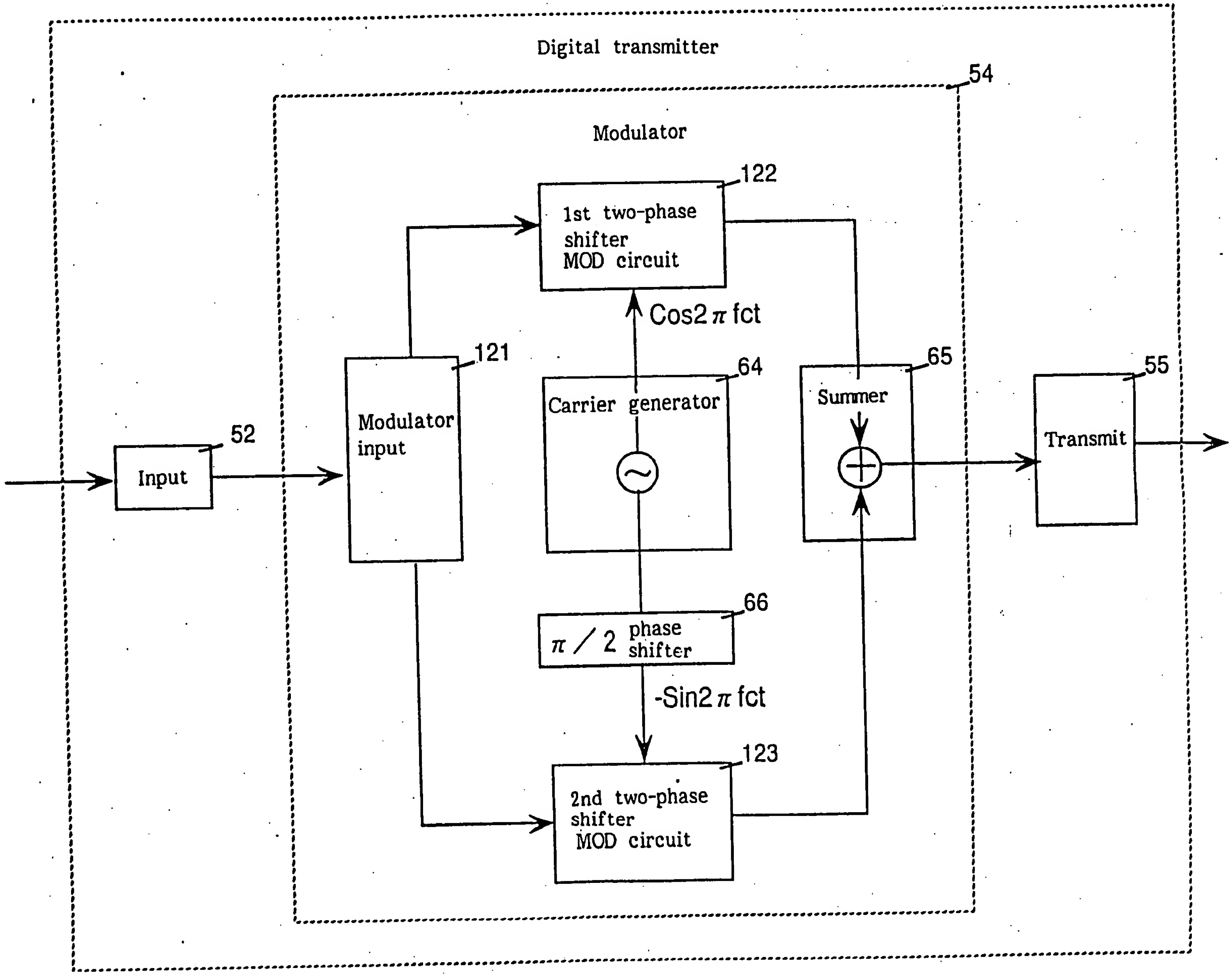

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Fig.18

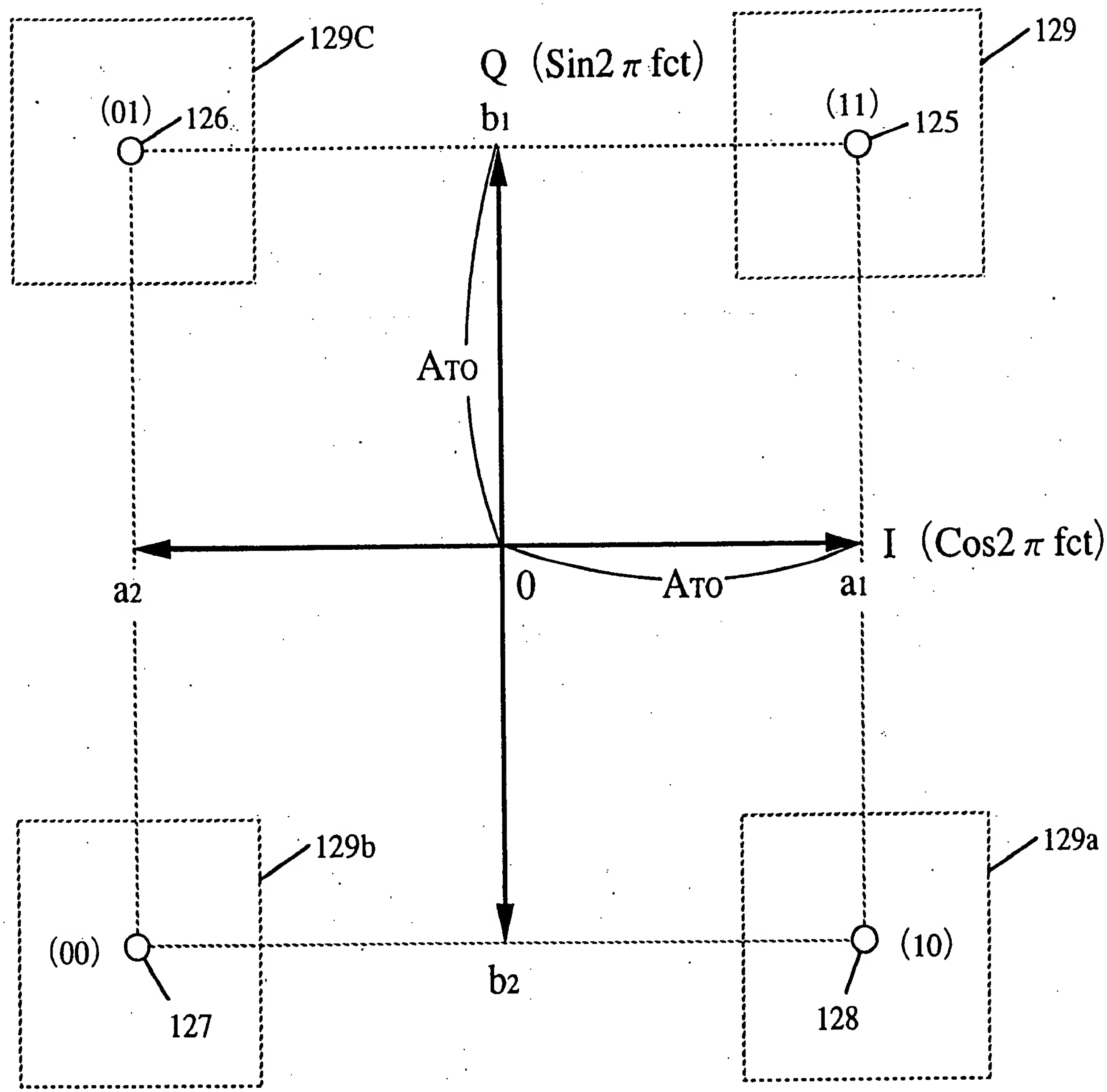

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FIG.19

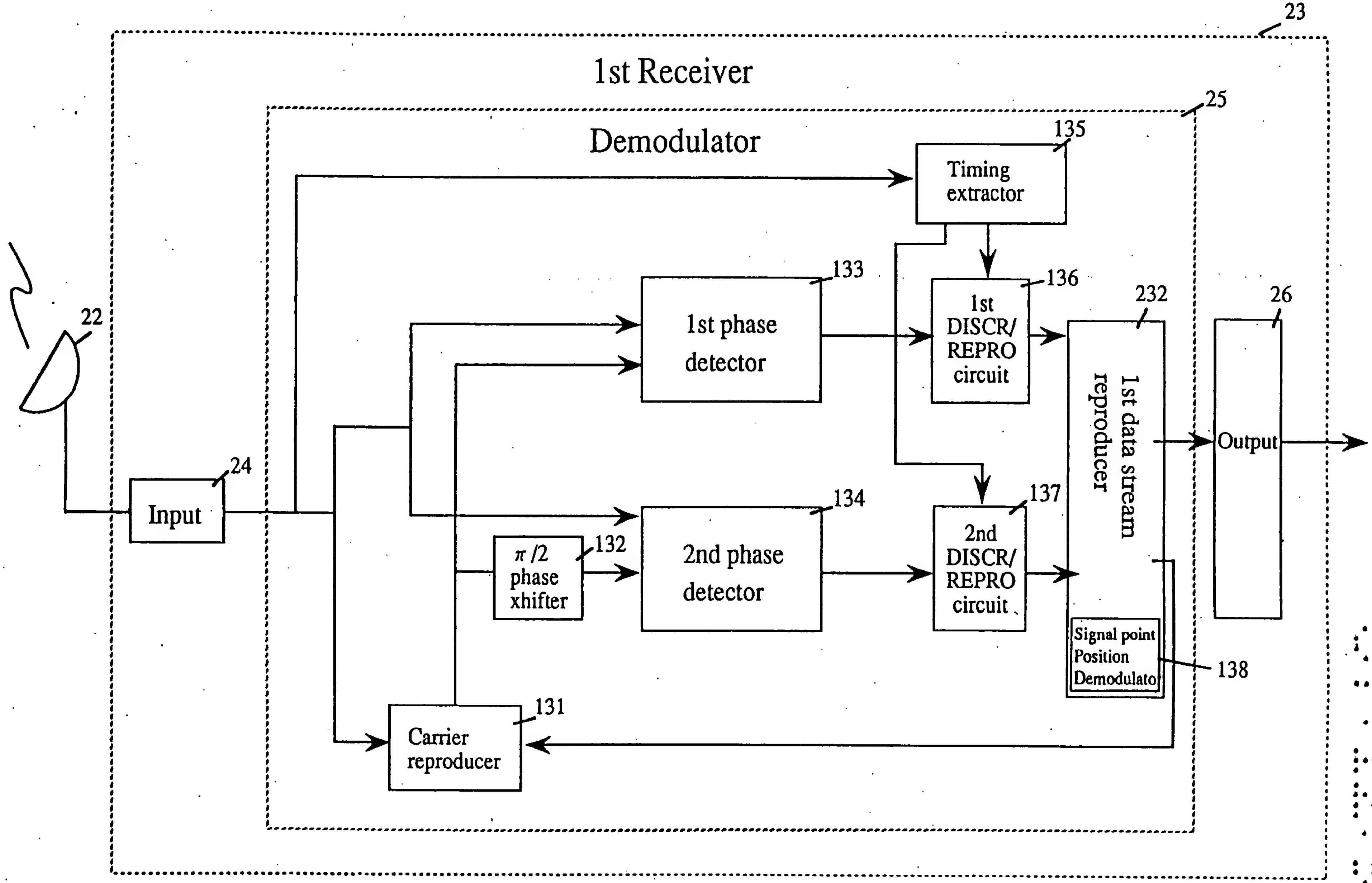

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FIG.20

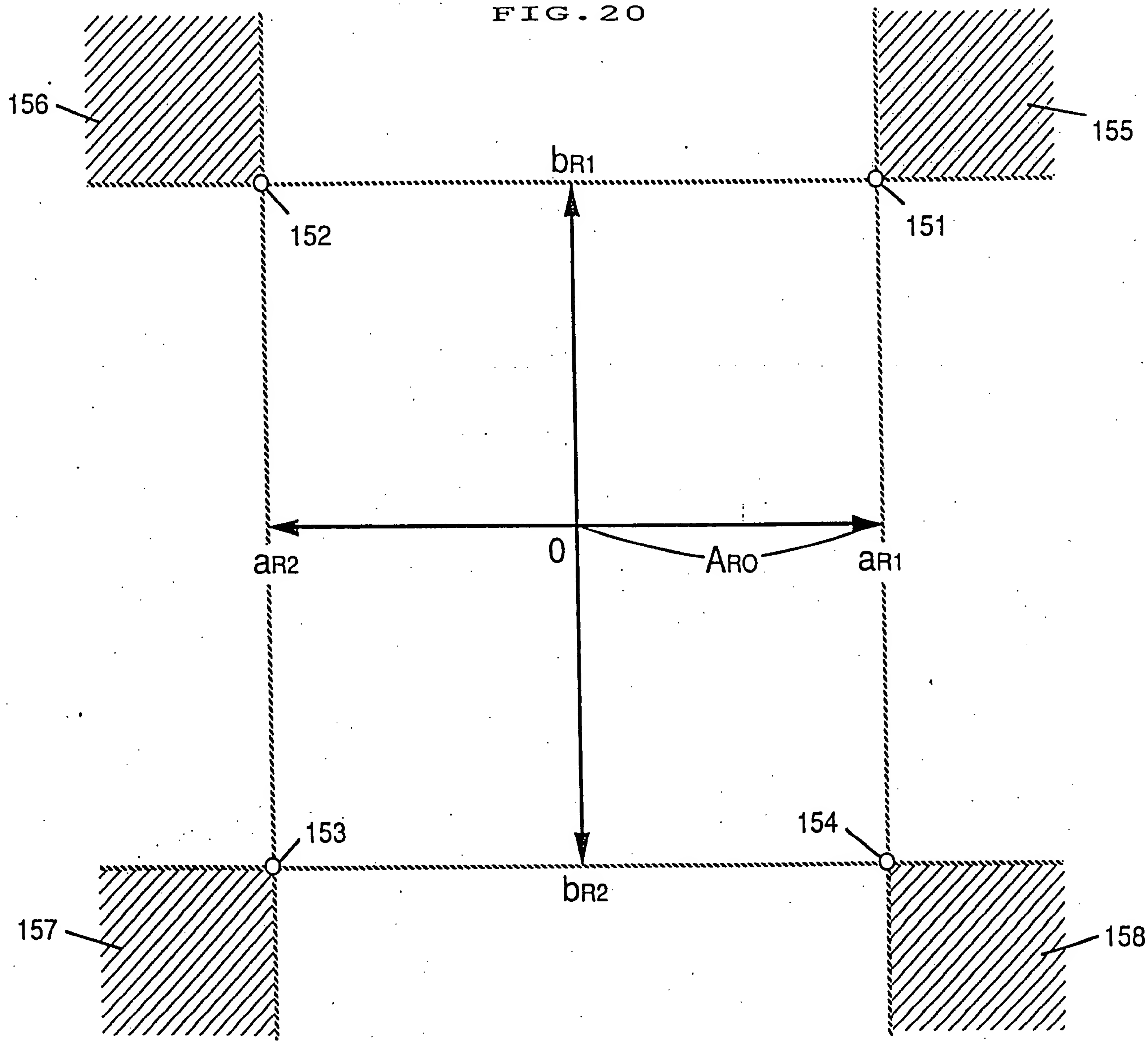


FIG.21

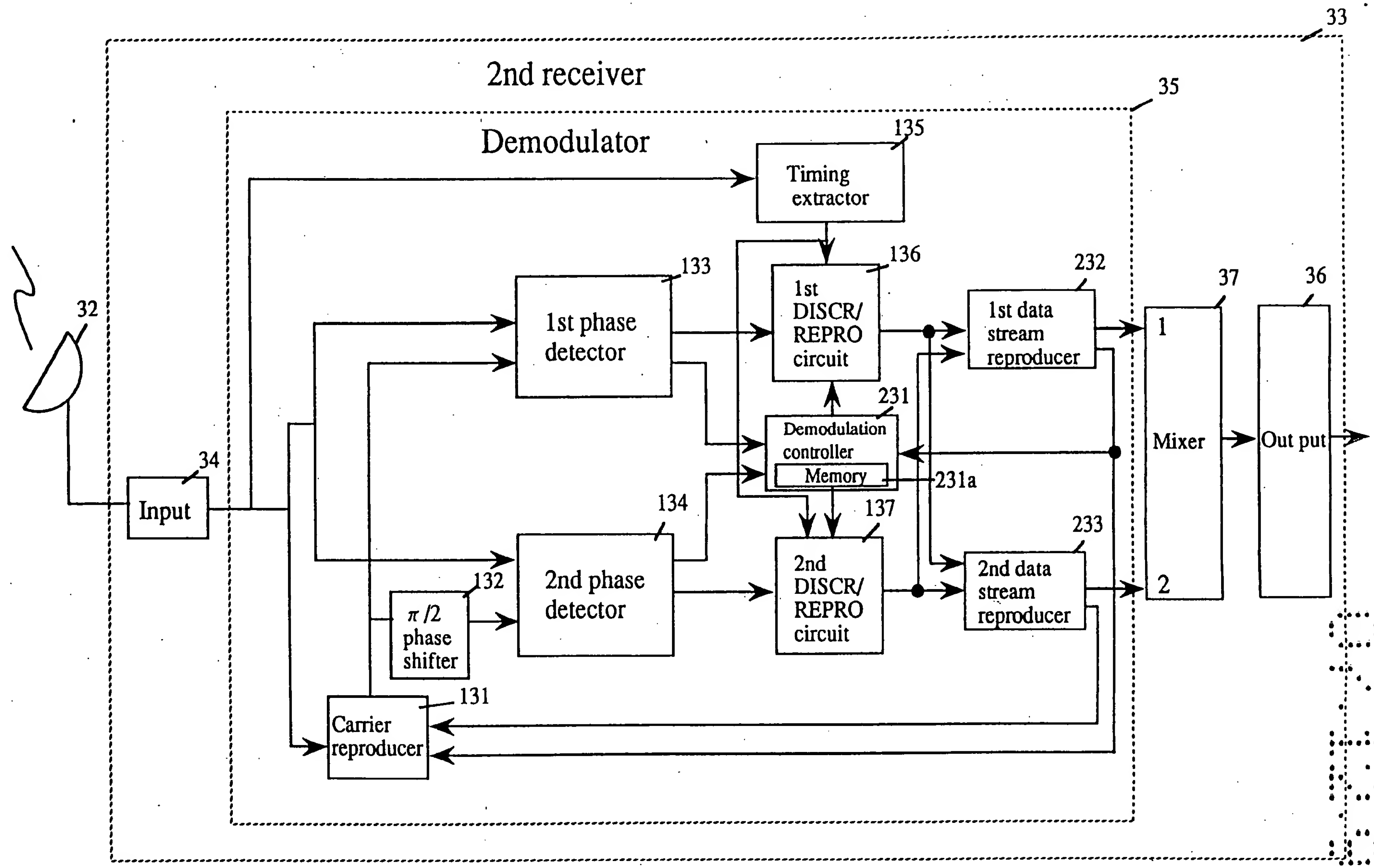
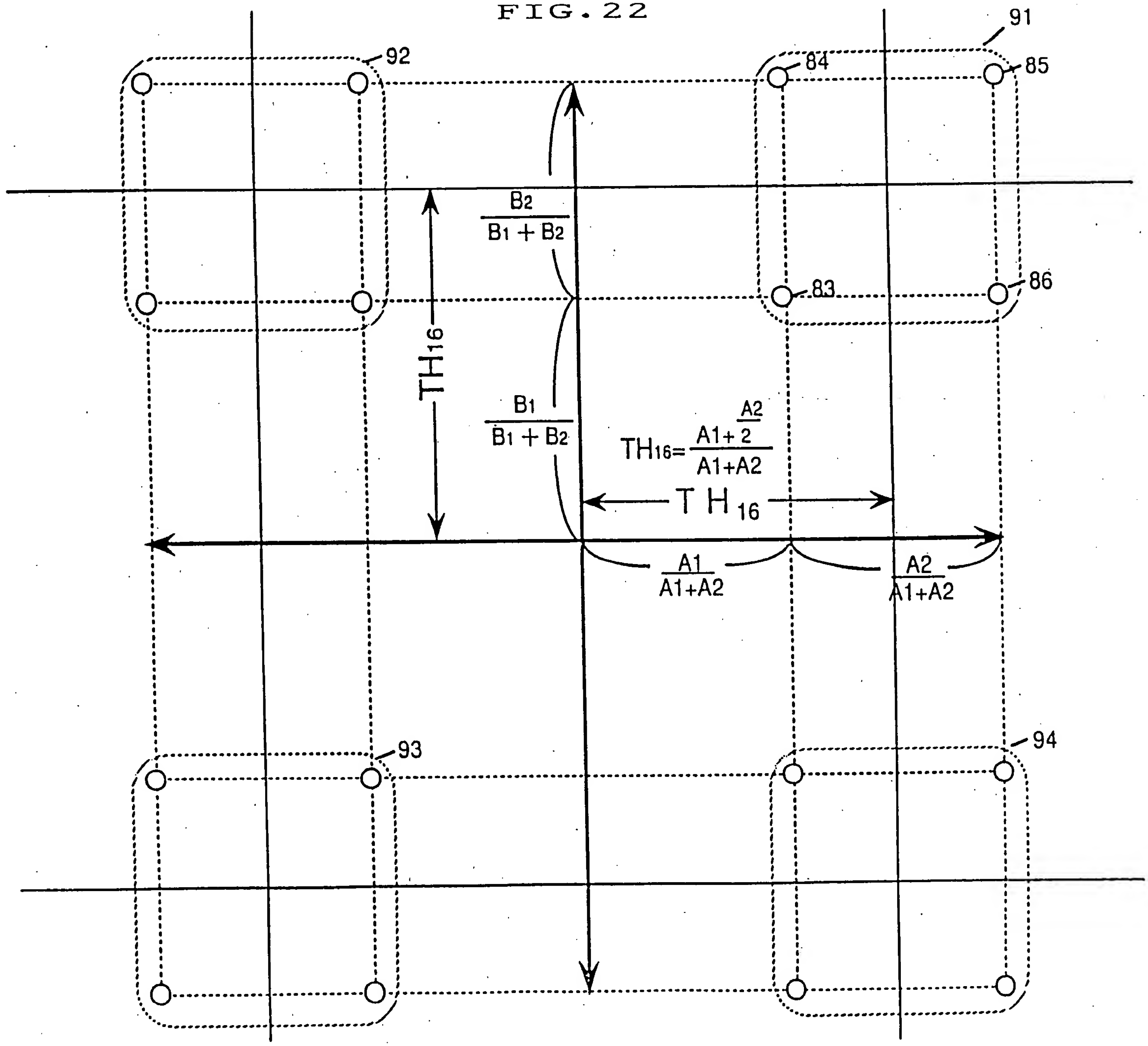

2nd receiver
33
Demodulator
35
32
Input
34
Timing extractor
135
1st phase detector
133
2nd phase detector
134
π /2 phase shifter
132
Carrier reproducer
131
1st DISCR/ REPRO circuit
136
2nd DISCR/ REPRO circuit
137
Demodulation controller
231
Memory
231a
1st data stream reproducer
232
2nd data stream reproducer
233
Mixer
1
2
37
Out put
36

FIG. 22



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07.12.92

FIG. 23

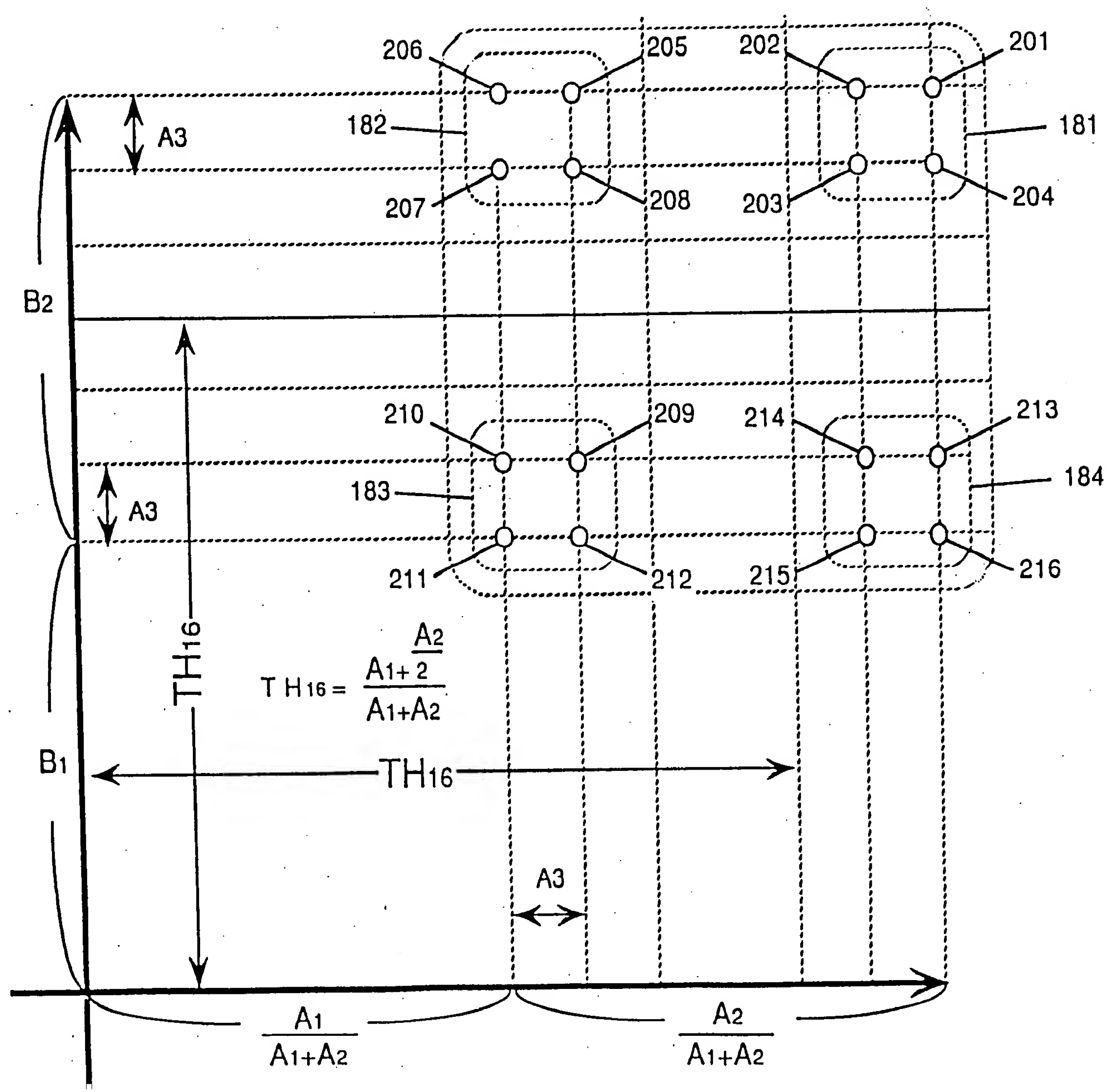


FIG. 24 07.12.92

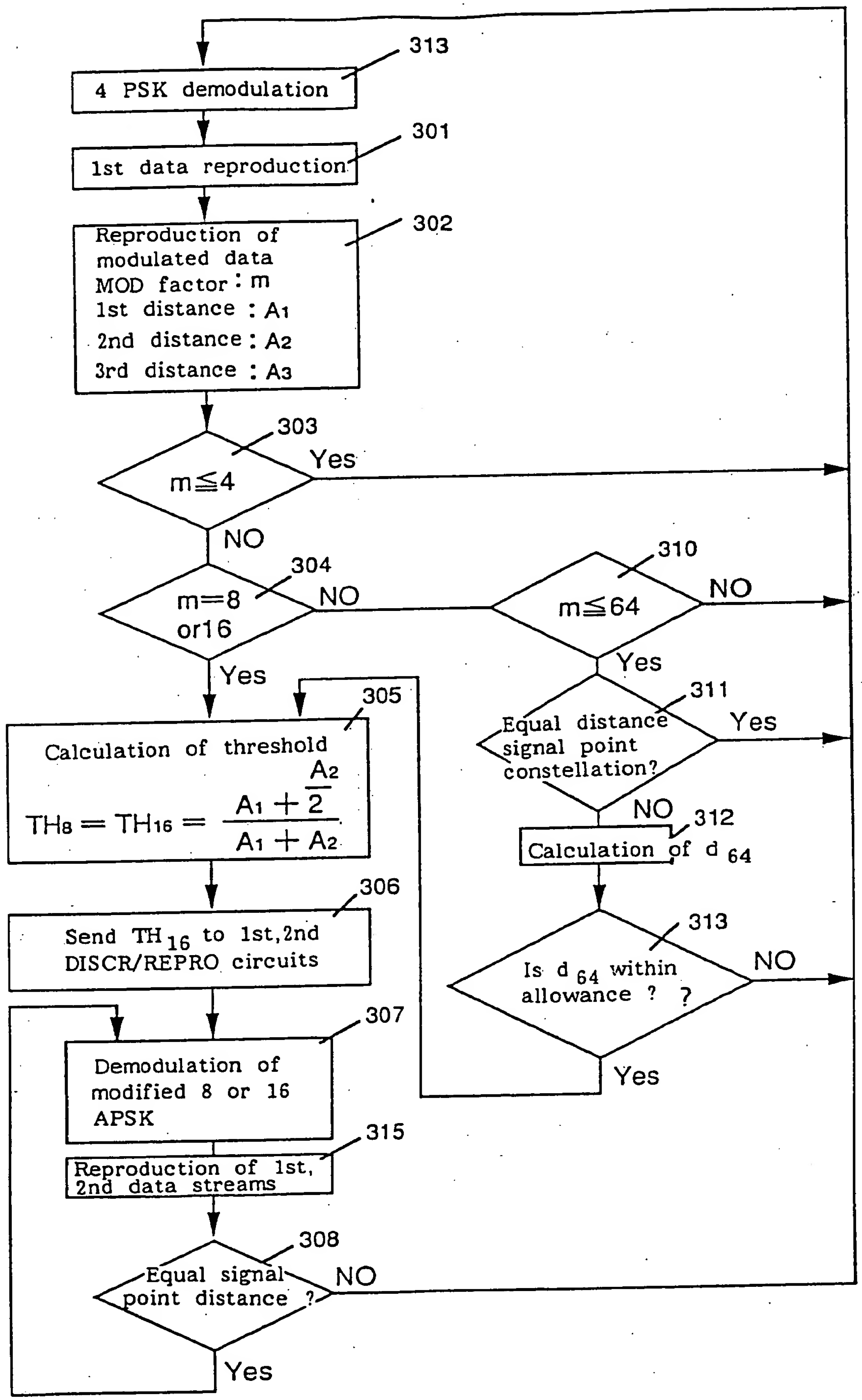
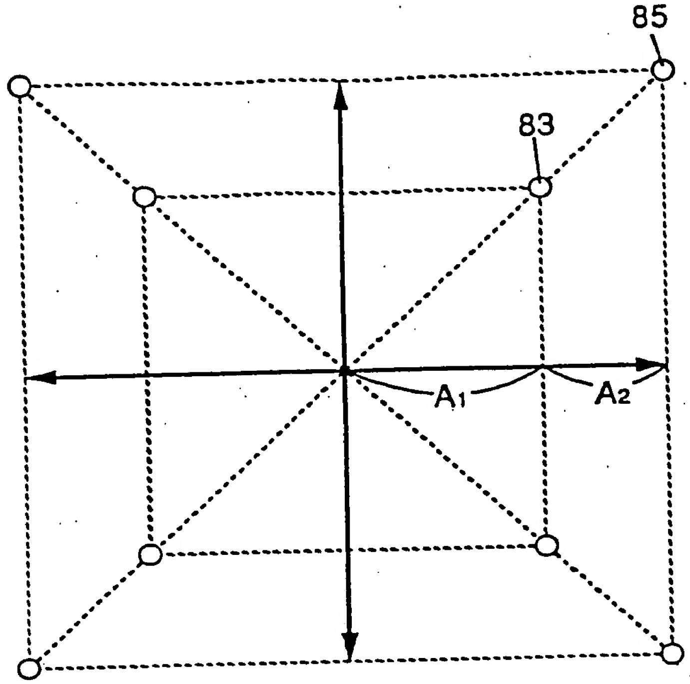


FIG. 25 07.12.92

(a)



(b)

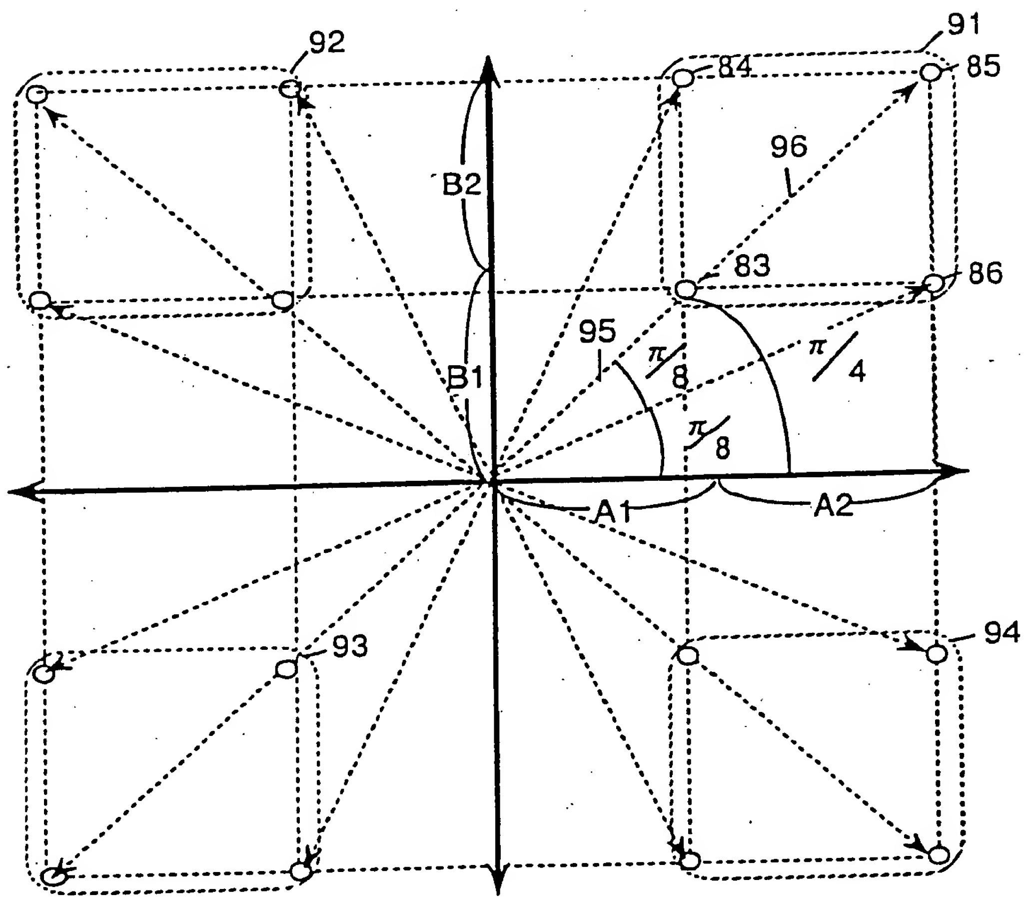


FIG.26

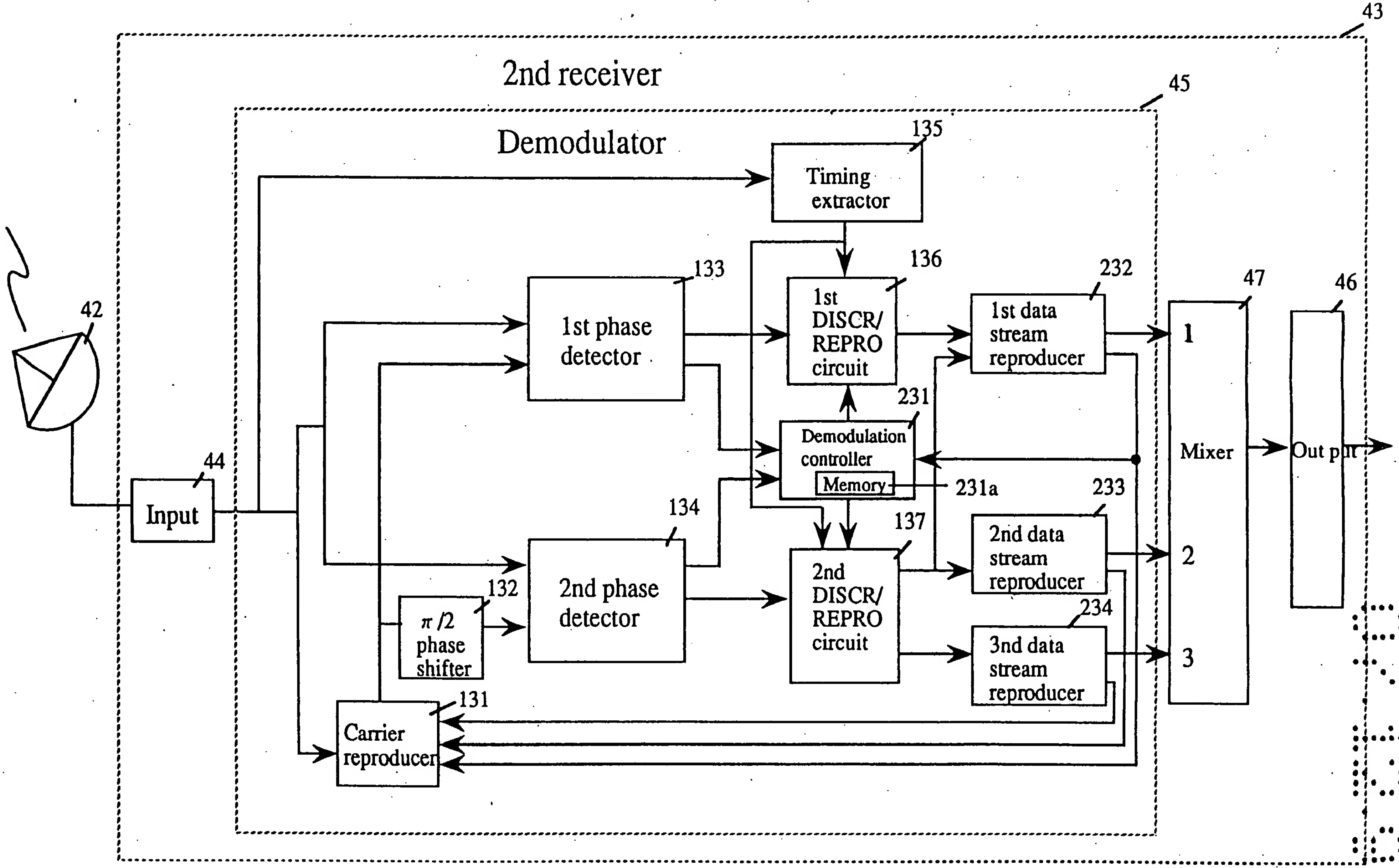

43
2nd receiver
45
Demodulator
42
44
Input
135
Timing extractor
133
1st phase detector
134
2nd phase detector
132
π/2 phase shifter
131
Carrier reproducer
136
1st DISCR/ REPRO circuit
231
Demodulation controller
Memory
231a
137
2nd DISCR/ REPRO circuit
232
1st data stream reproducer
233
2nd data stream reproducer
234
3nd data stream reproducer
47
Mixer
1
2
3
46
Out put

FIG. 27

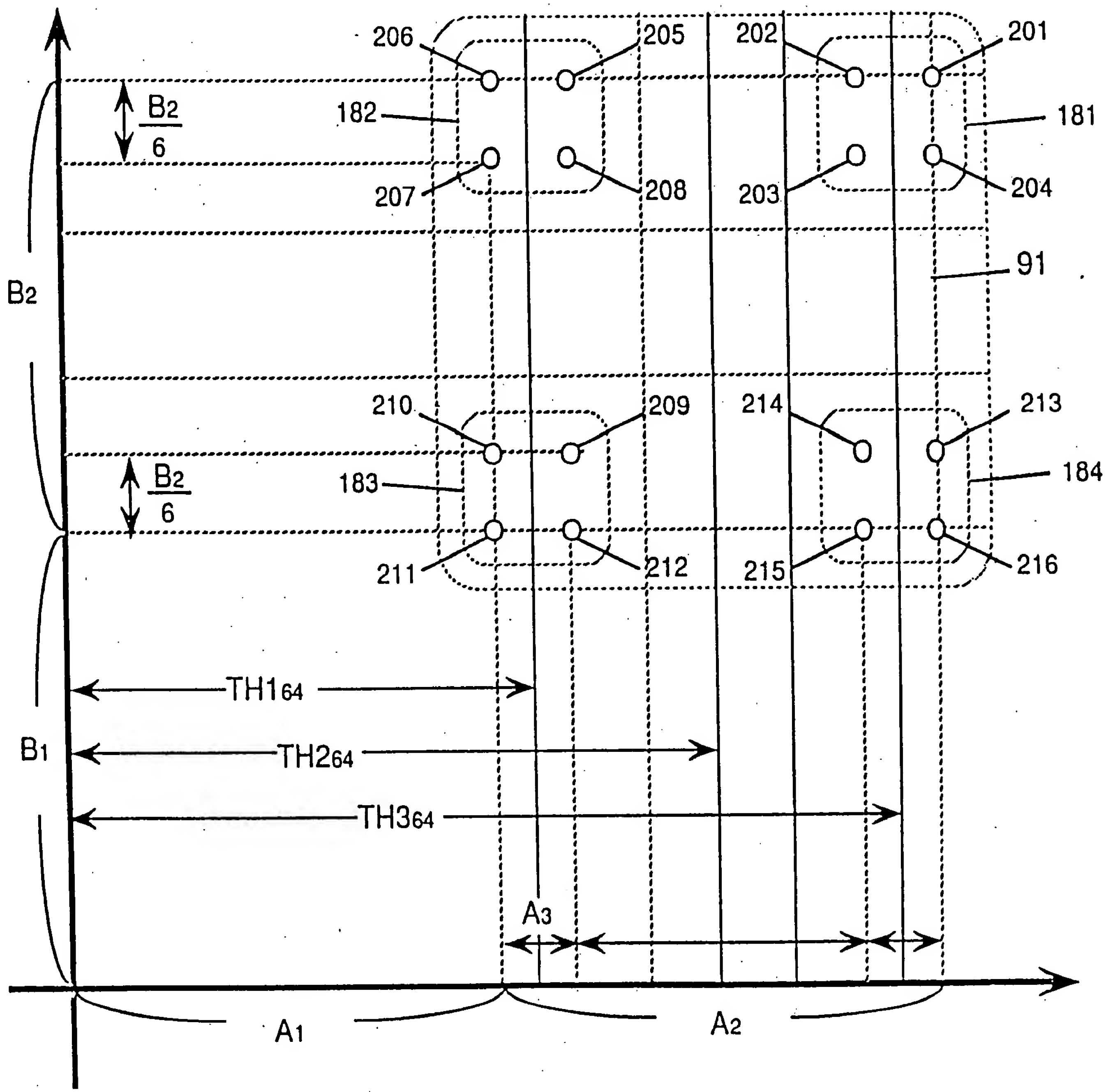


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FIG. 28 07.12.92

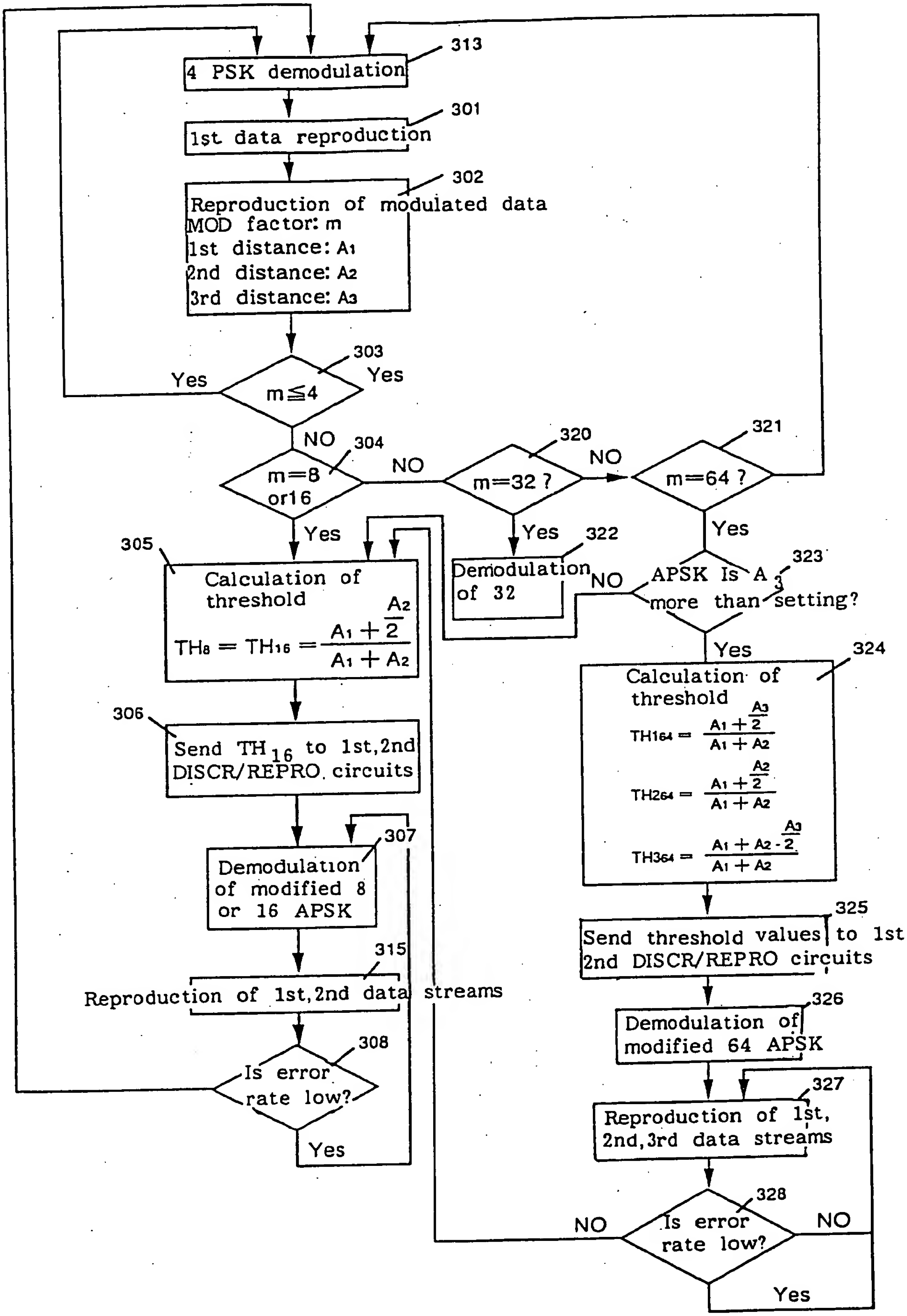
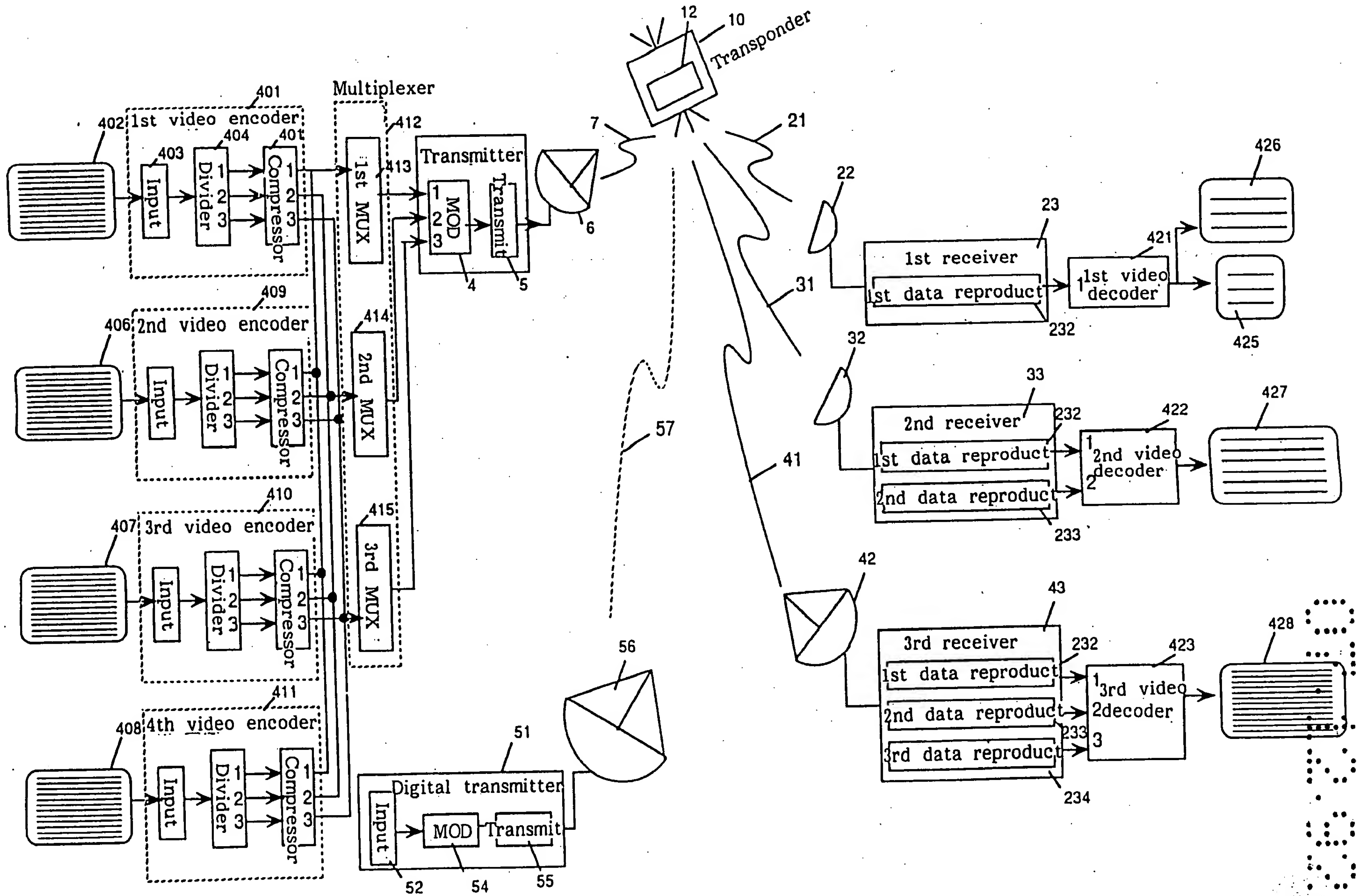
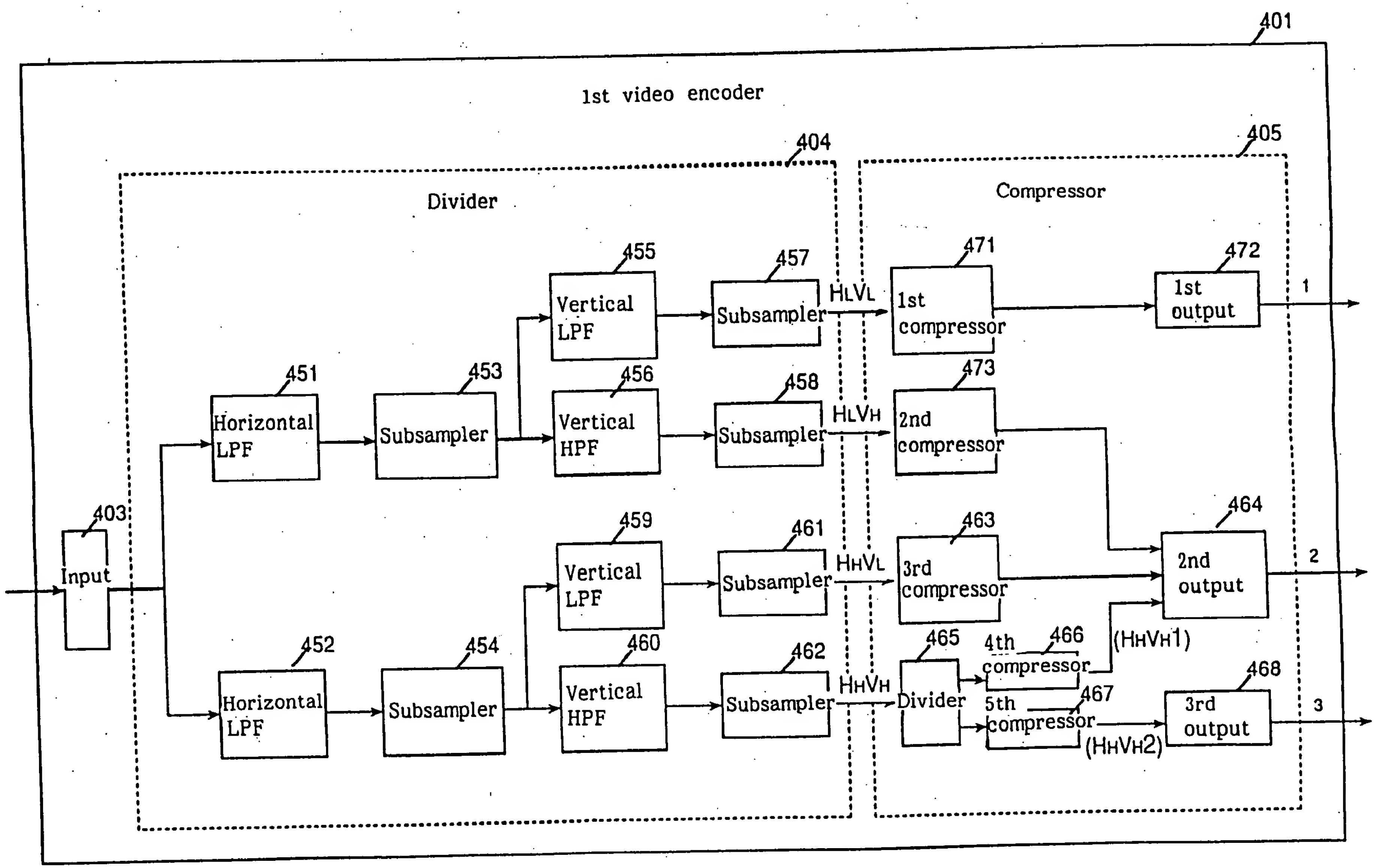


FIG. 29



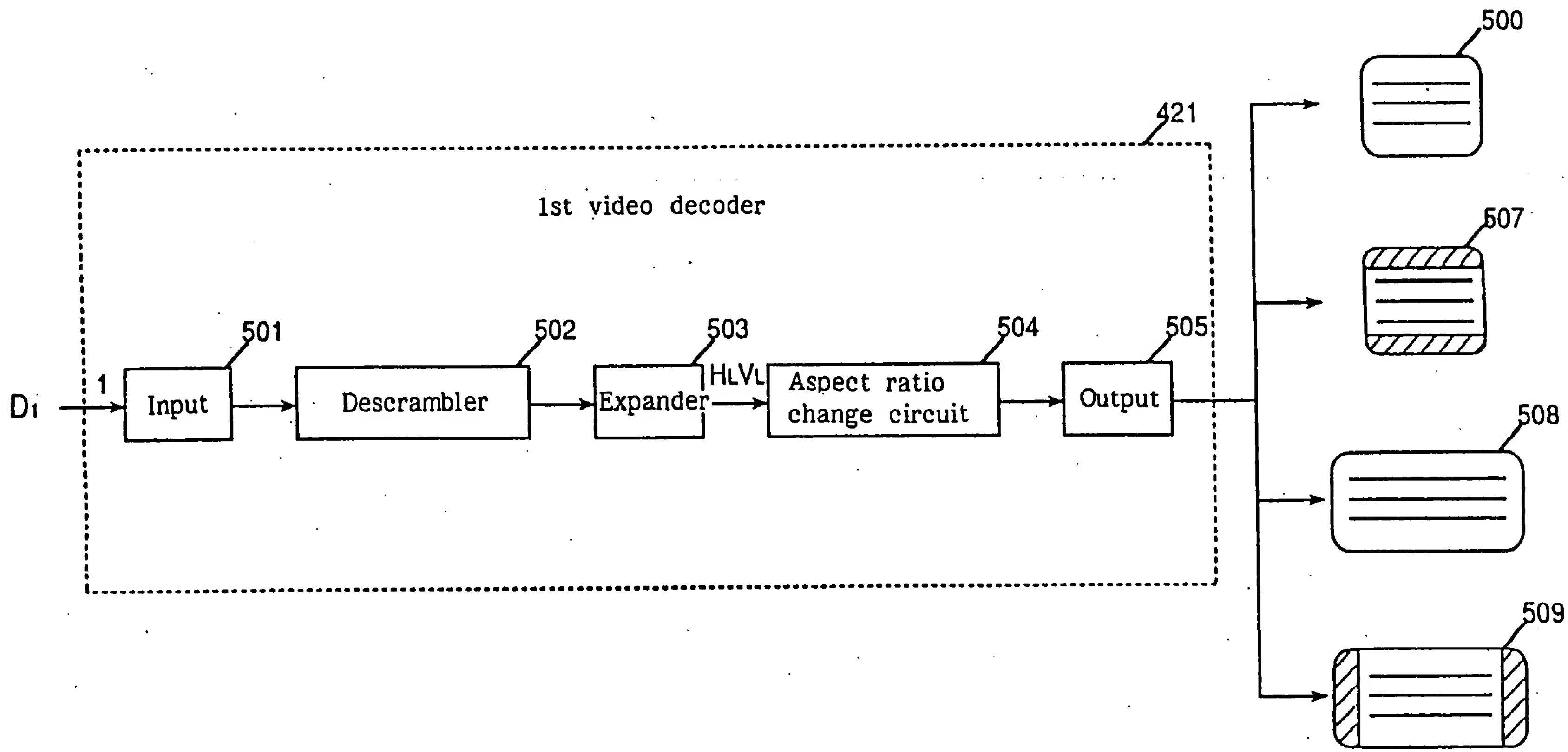
Transponder
12
10
7
21
6
22
31
32
41
42
57
56
1st video encoder
2nd video encoder
3rd video encoder
4th video encoder
Input
Divider
Compressor
Multiplexer
1st MUX
2nd MUX
3rd MUX
Transmitter
MOD
Transmit
Digital transmitter
1st receiver
2nd receiver
3rd receiver
1st data reproduct
2nd data reproduct
3rd data reproduct
1st video decoder
2nd video decoder
3rd video decoder
401
402
403
404
406
407
408
409
410
411
412
413
414
415
4
5
51
52
54
55
23
33
43
232
233
234
421
422
423
425
426
427
428

FIG. 30



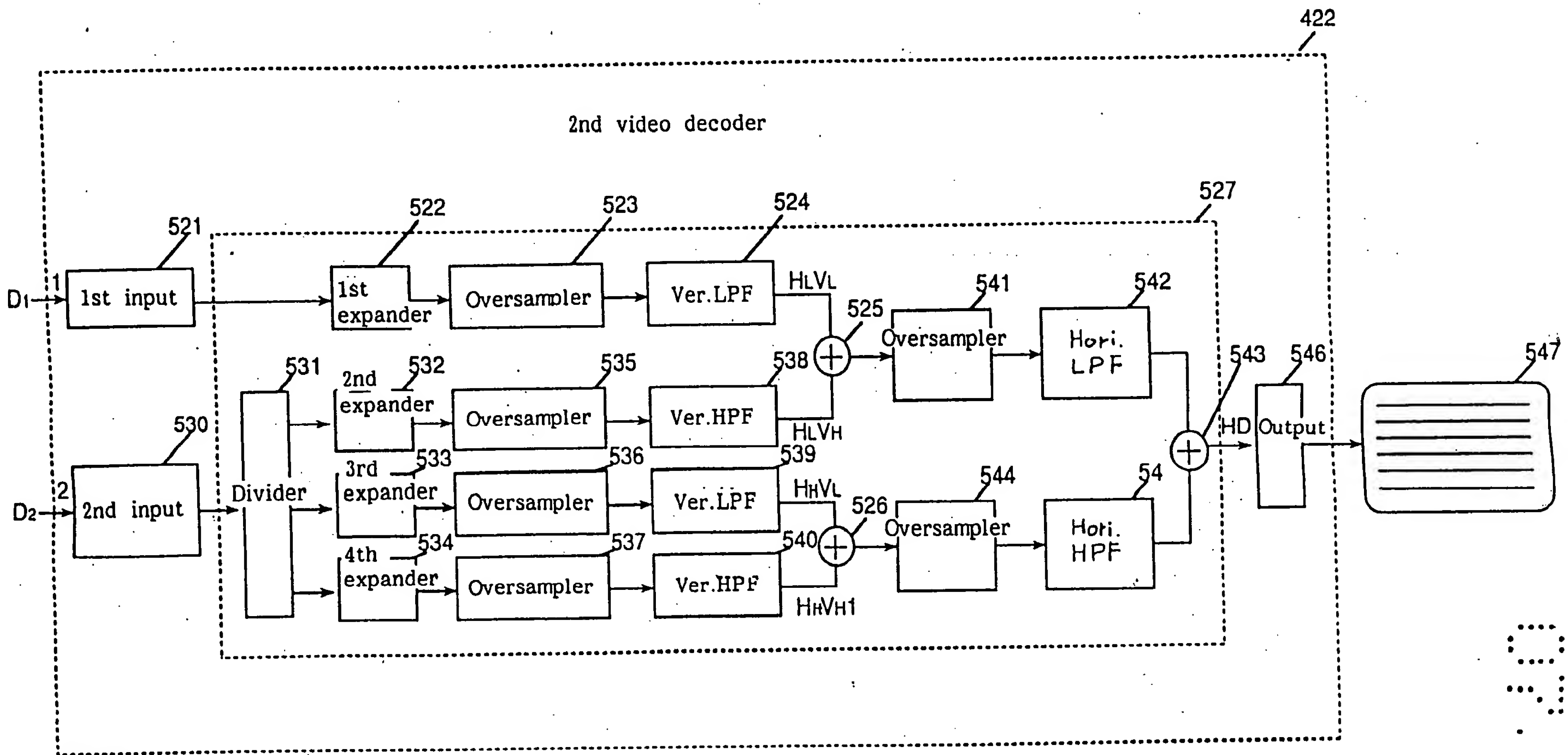
07.12.92

FIG. 31



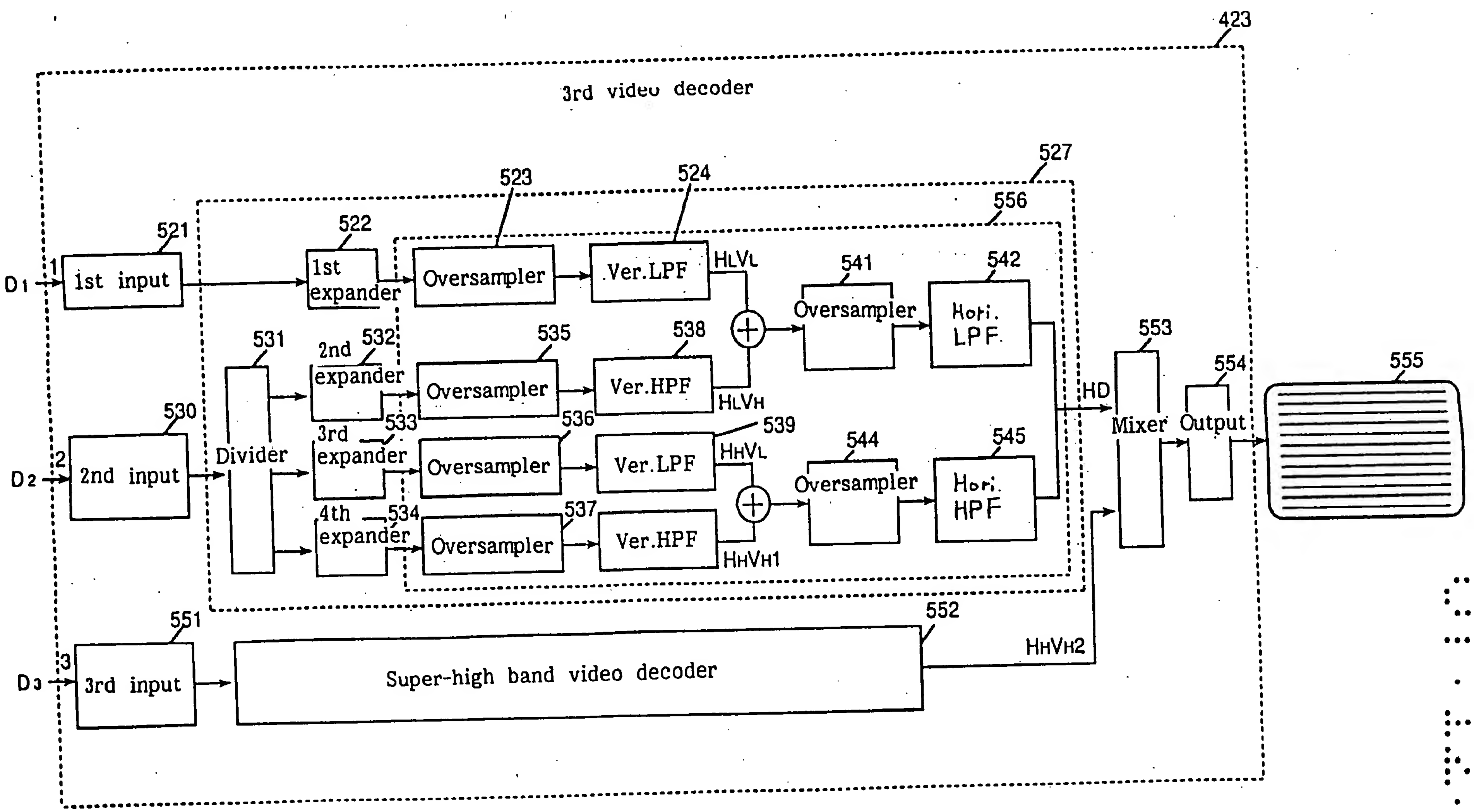
07.12.92

FIG. 32



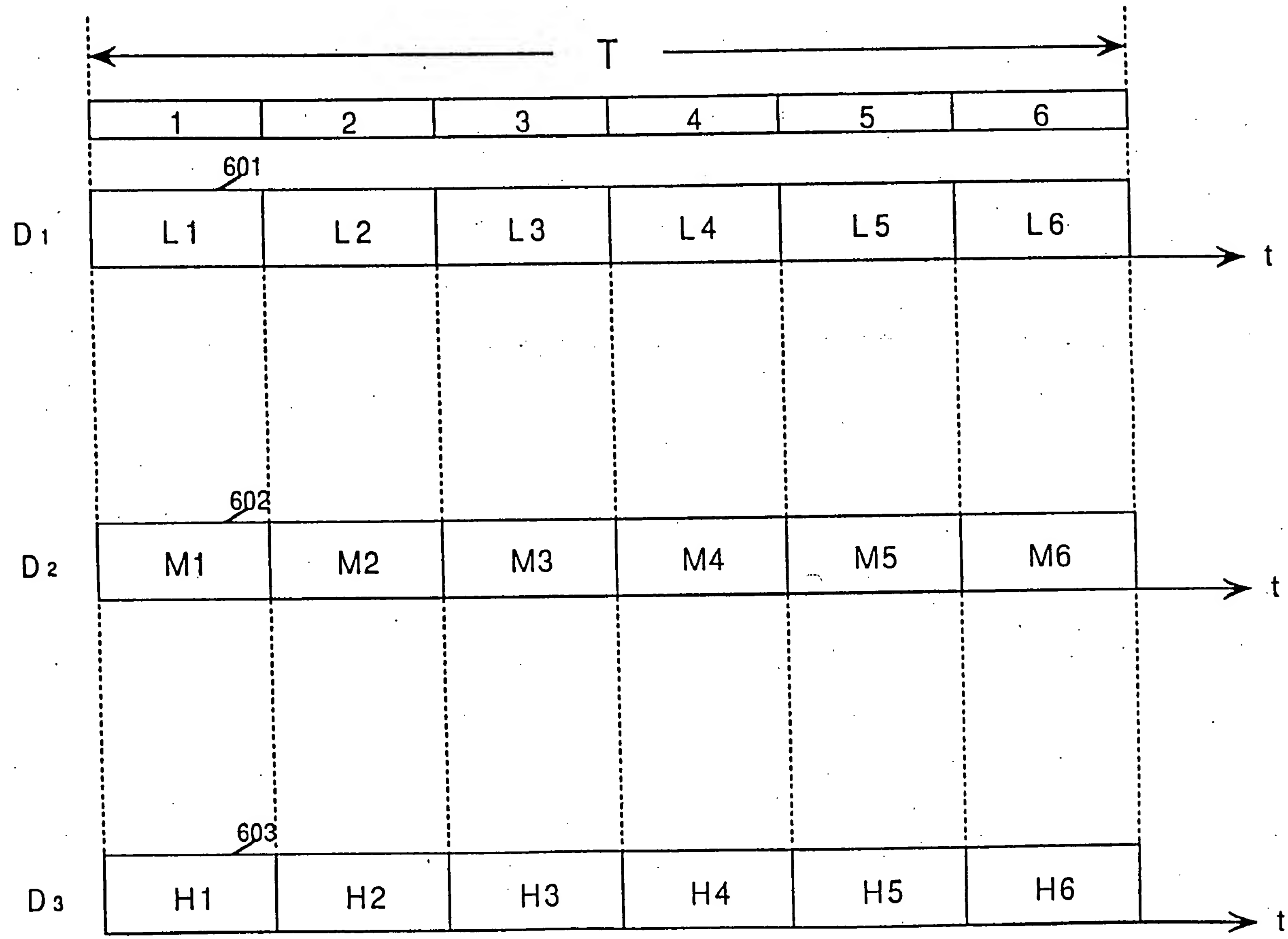
07.12.92

FIG. 33



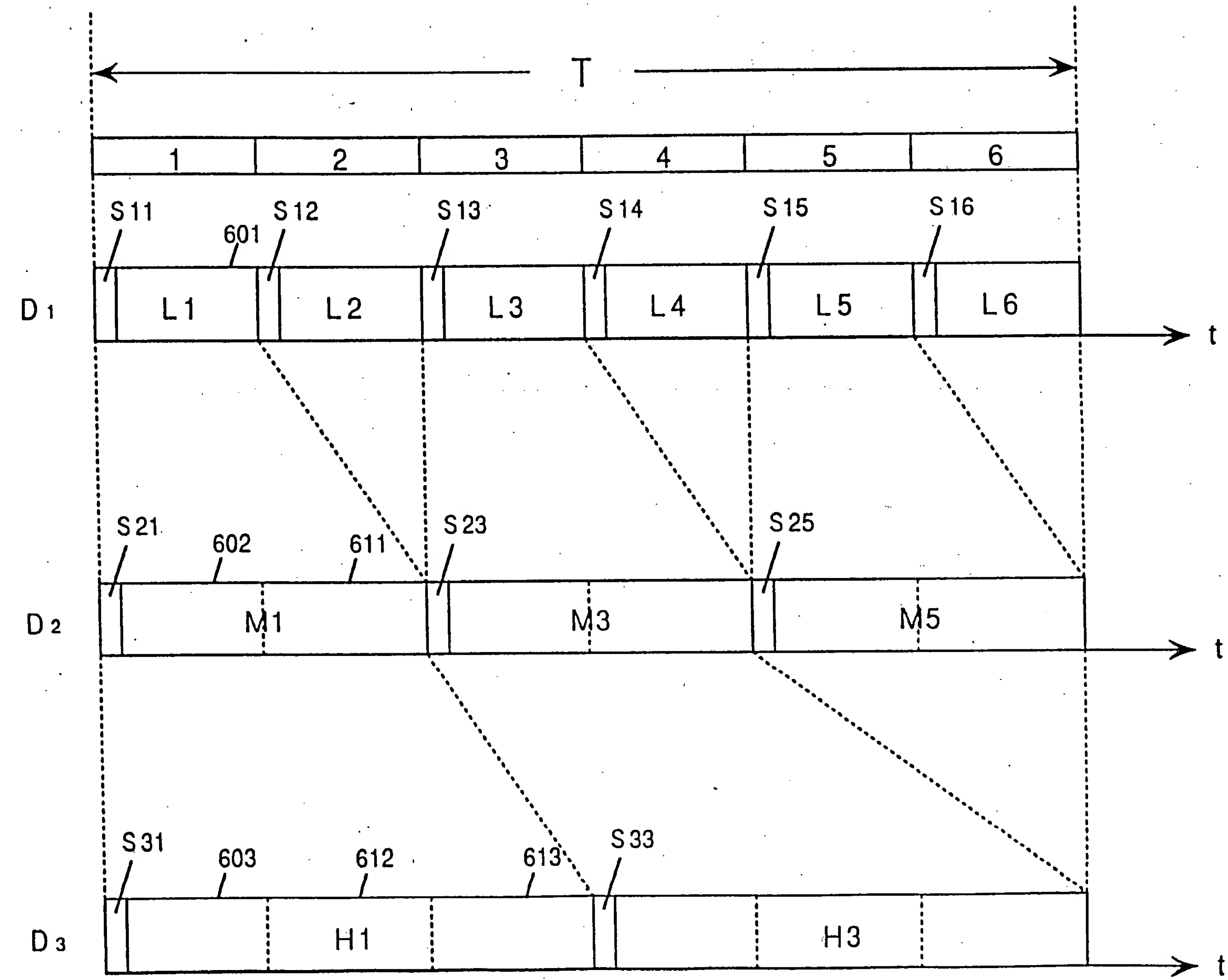
07.12.92

FIG. 34



T
1
2
3
4
5
6
601
D1
L1
L2
L3
L4
L5
L6
t
602
D2
M1
M2
M3
M4
M5
M6
t
603
D3
H1
H2
H3
H4
H5
H6
t

FIG.35



07.12.92

07.12.92

FIG. 36

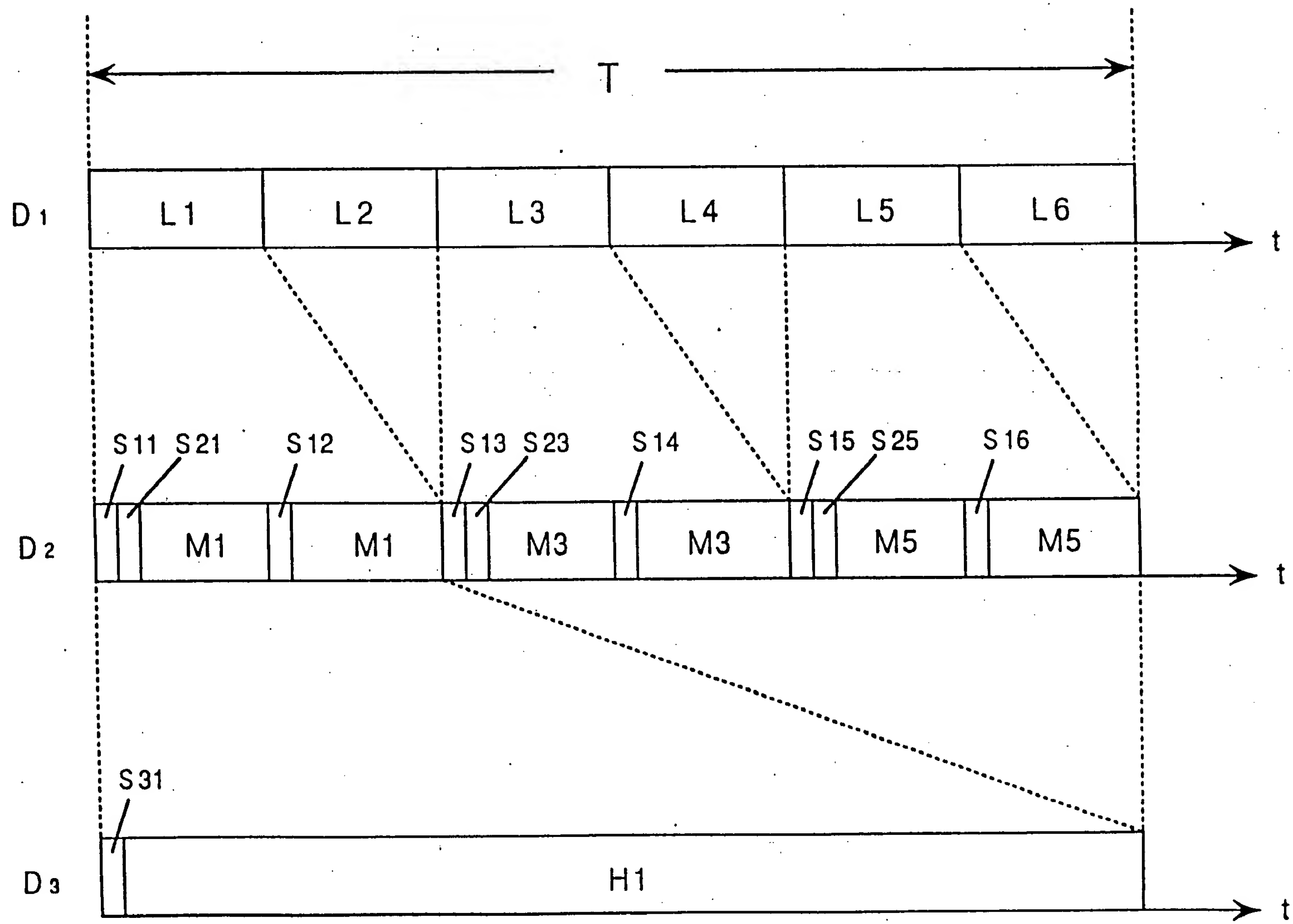
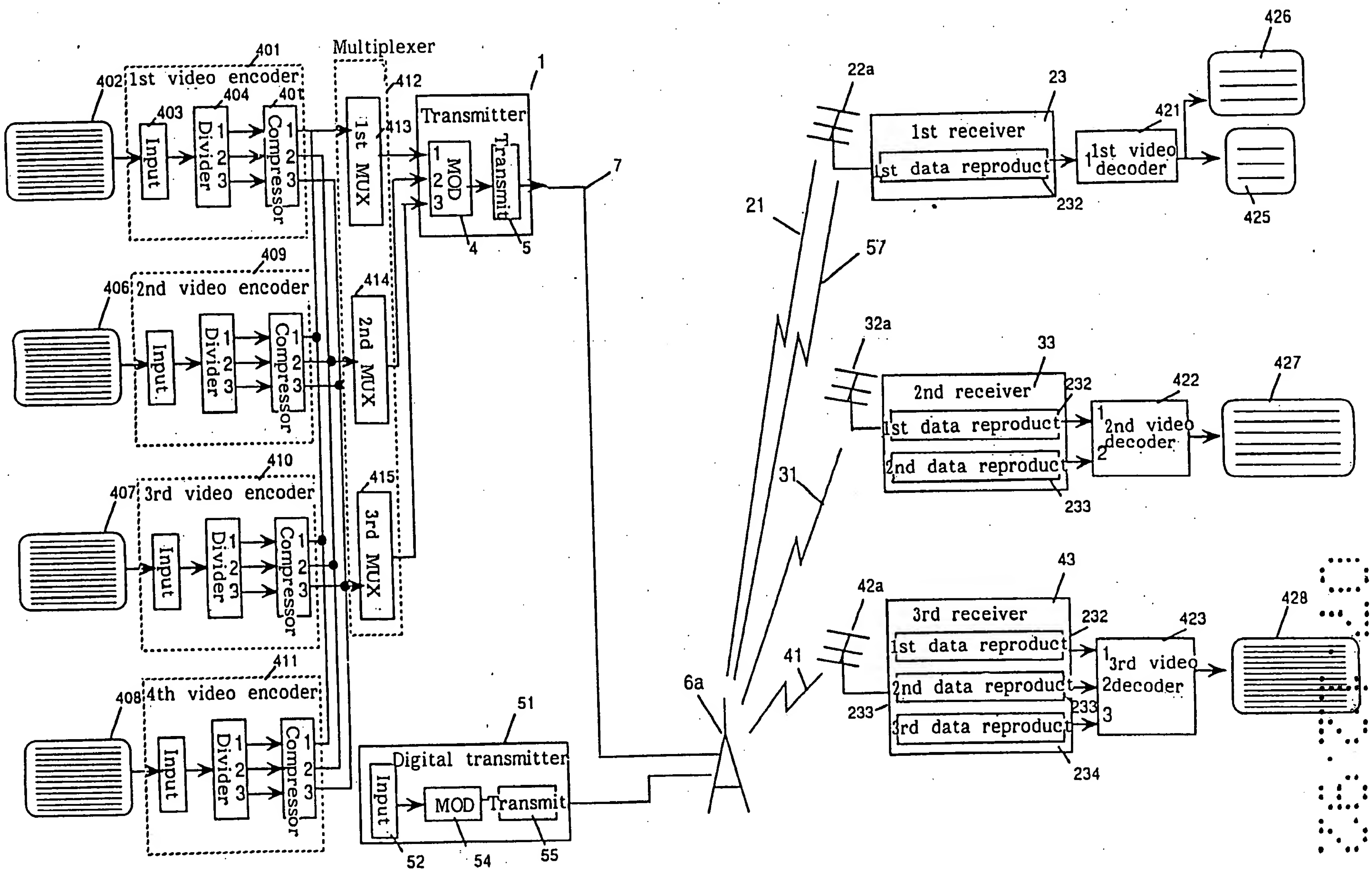
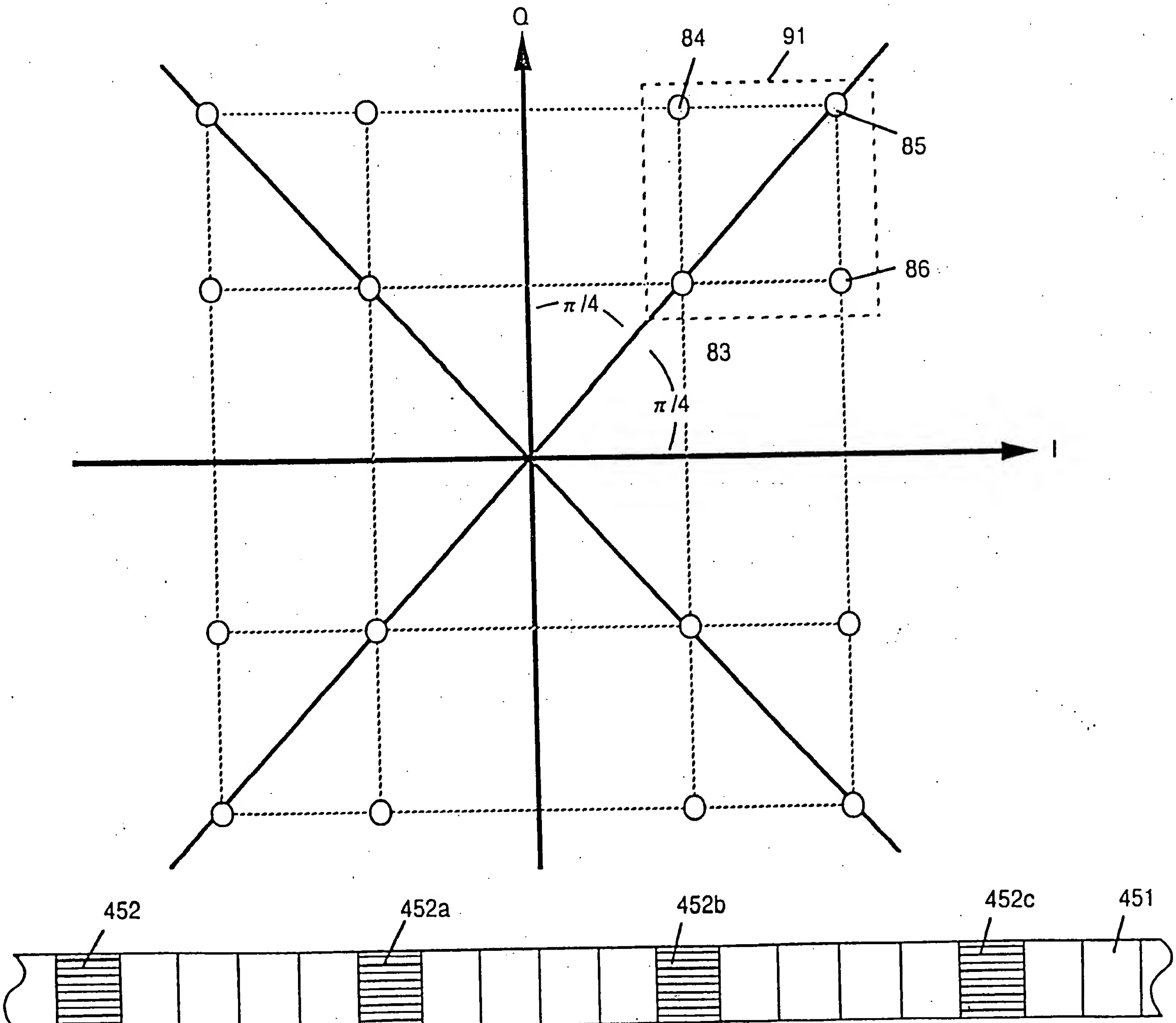


FIG. 37



1st video encoder
2nd video encoder
3rd video encoder
4th video encoder
Input
Divider
Compressor
Multiplexer
1st MUX
2nd MUX
3rd MUX
Transmitter
MOD
Transmit
Digital transmitter
1st receiver
2nd receiver
3rd receiver
1st data reproduct
2nd data reproduct
3rd data reproduct
1st video decoder
2nd video decoder
3rd video decoder

FIG.38



07.12.92

07.12.92

FIG. 39

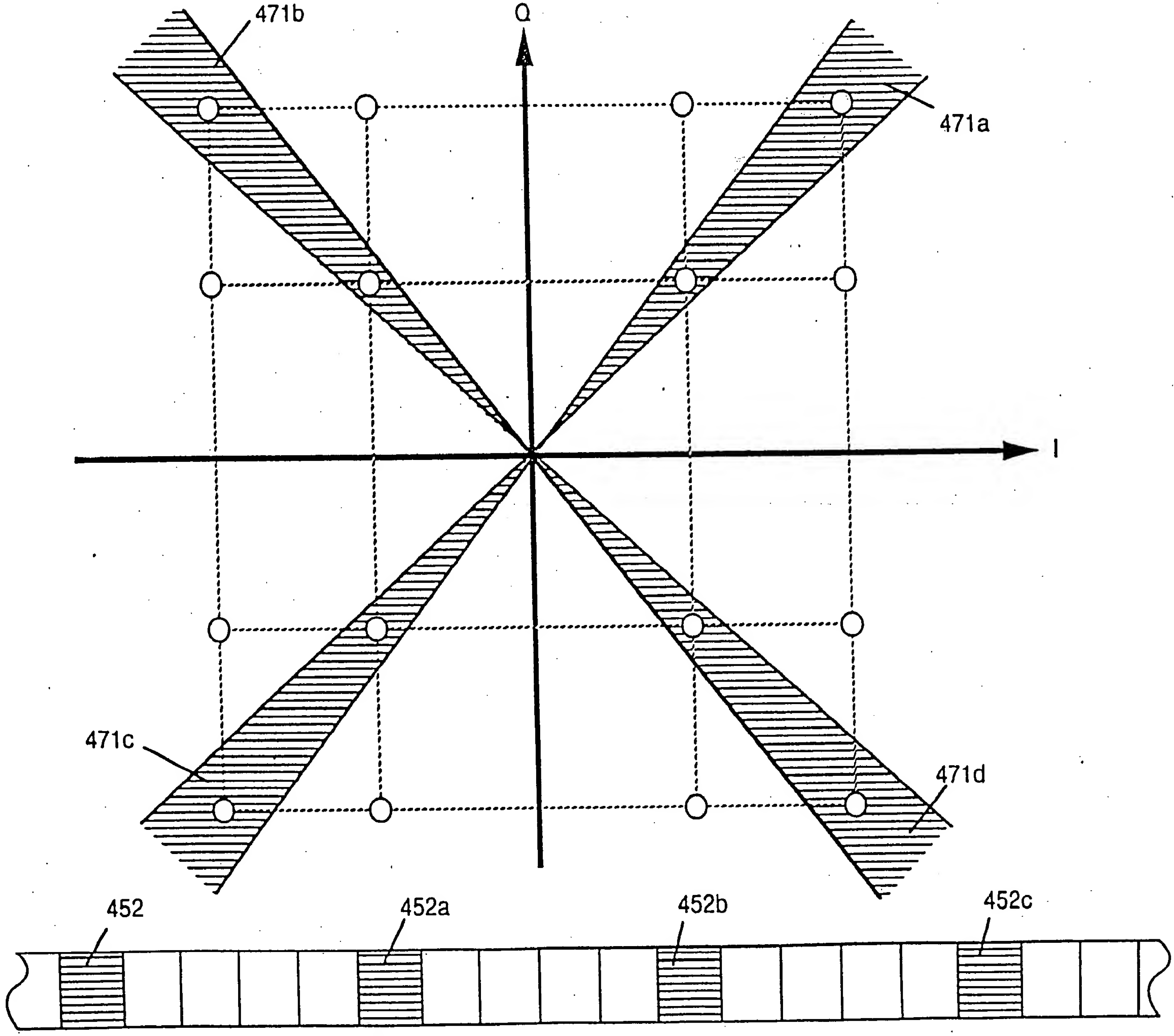
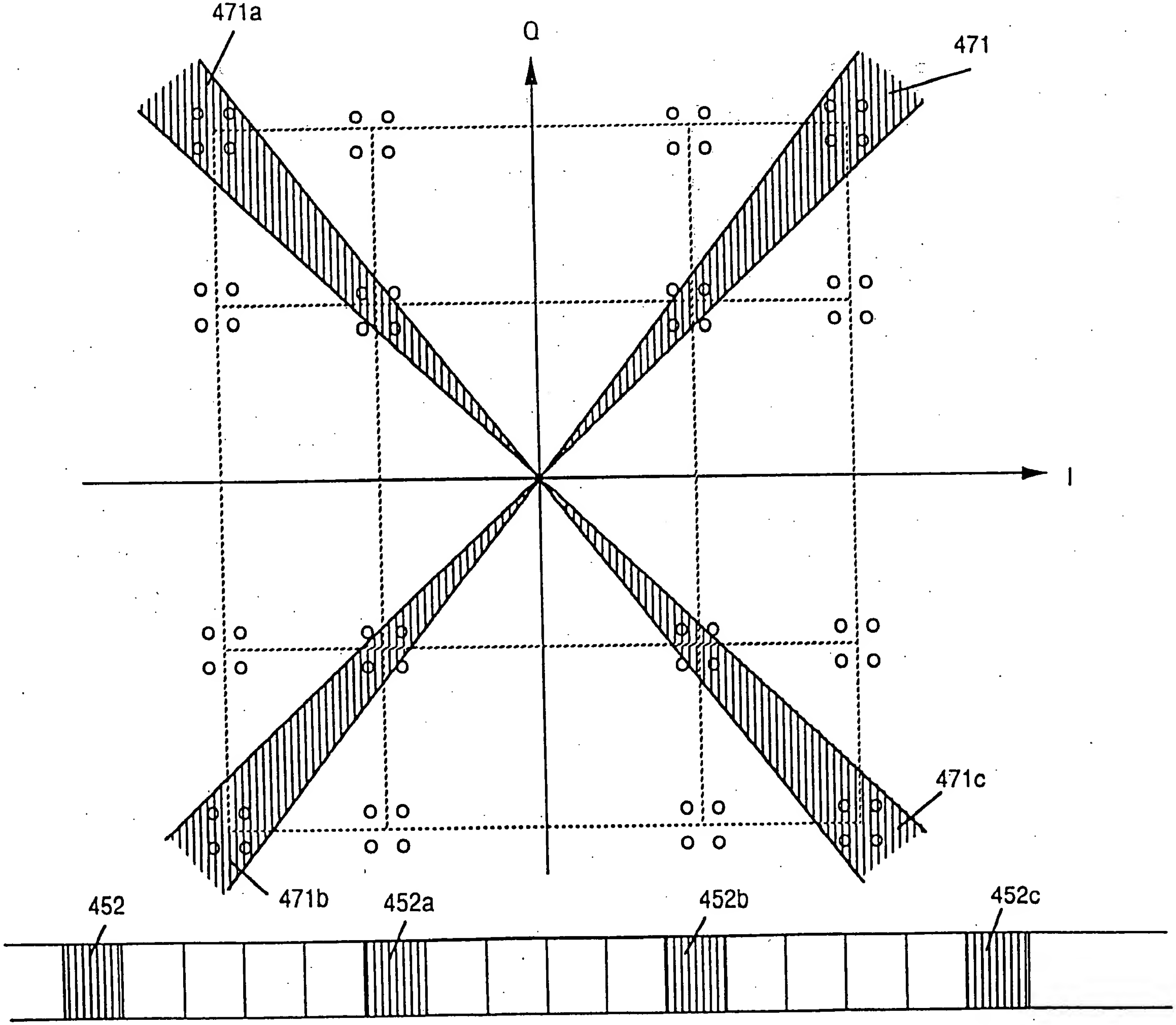
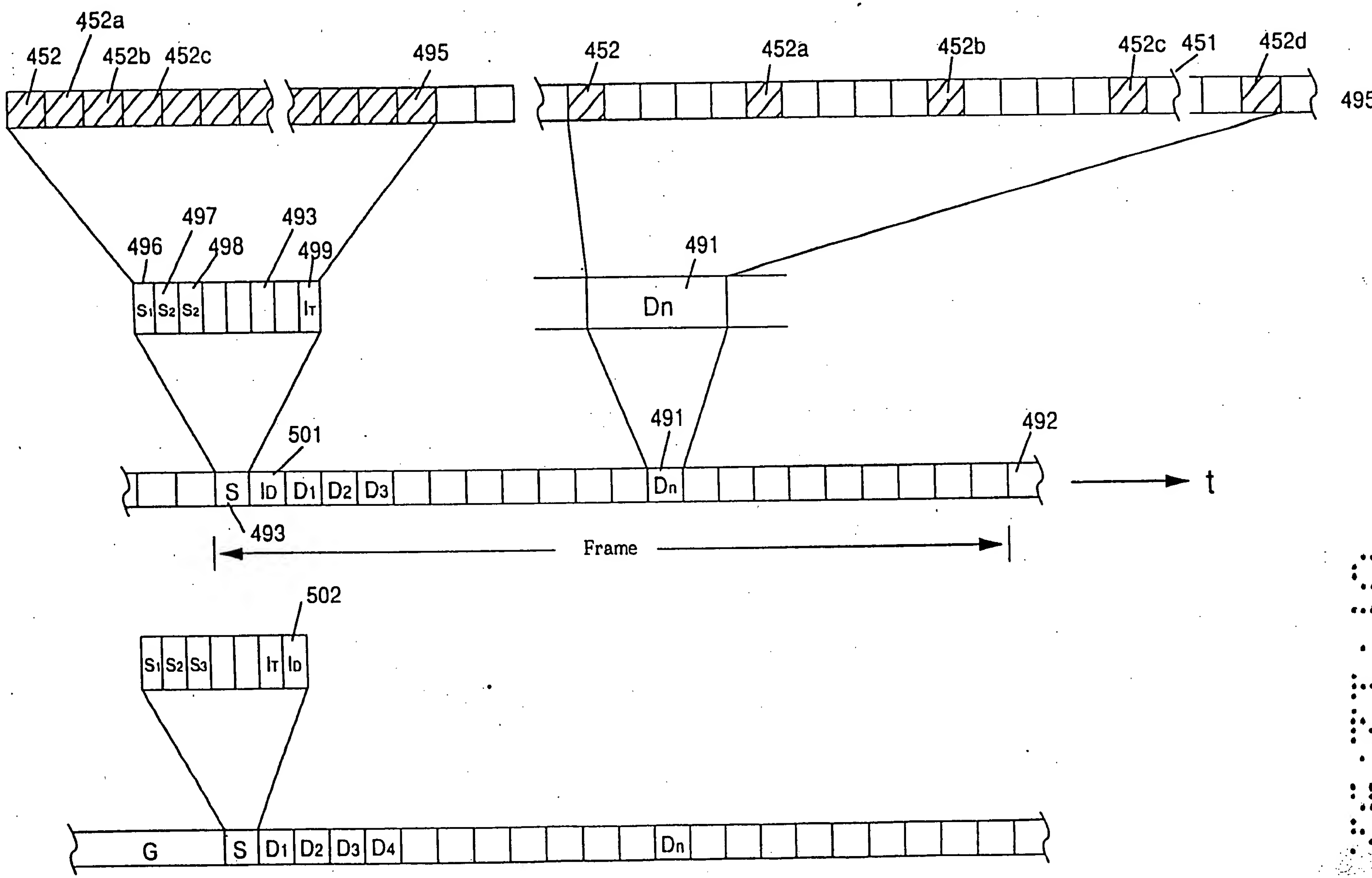


FIG. 40



07.12.92

FIG. 41



07.12.99

07.12.92

FIG. 42

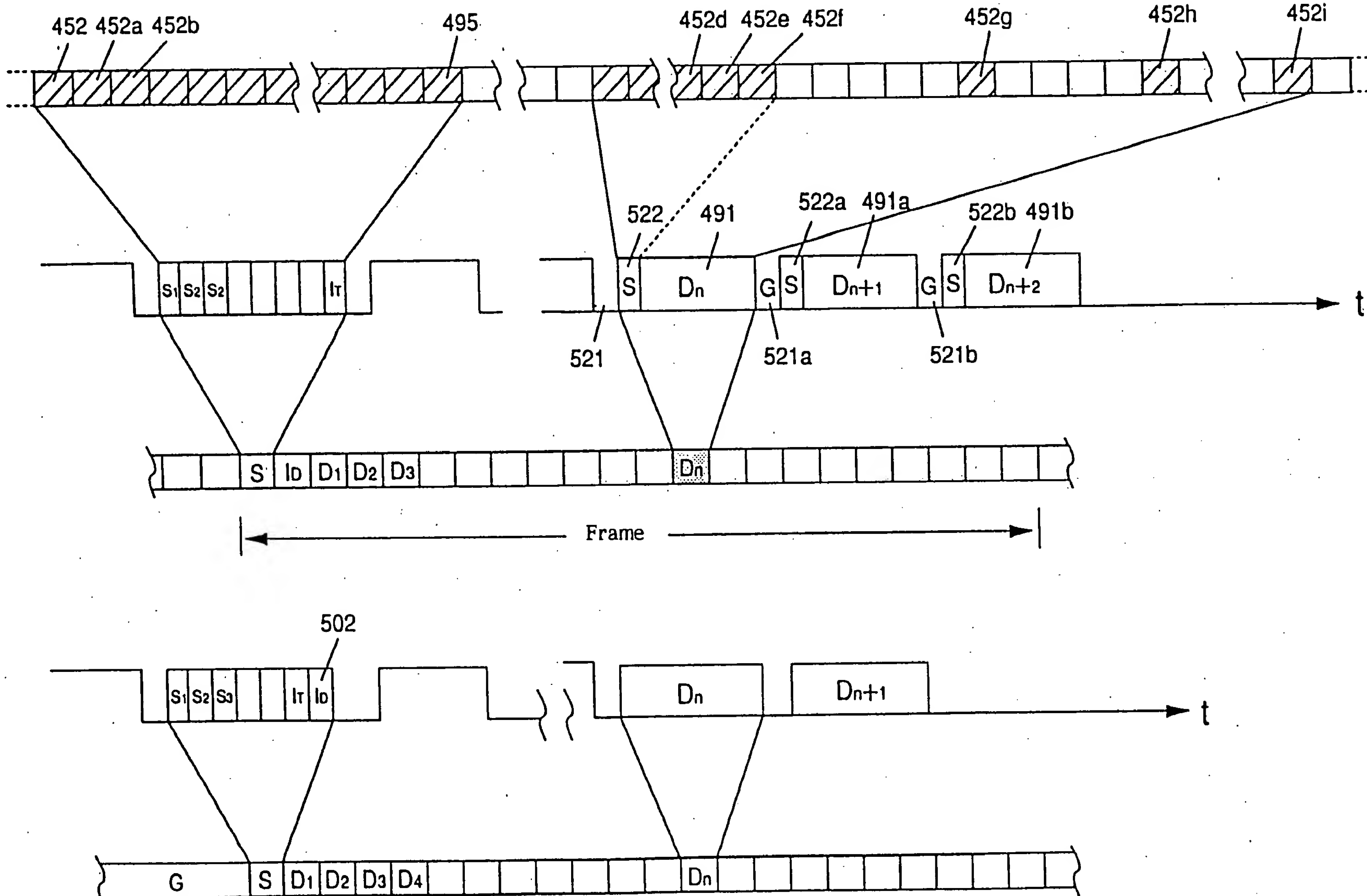
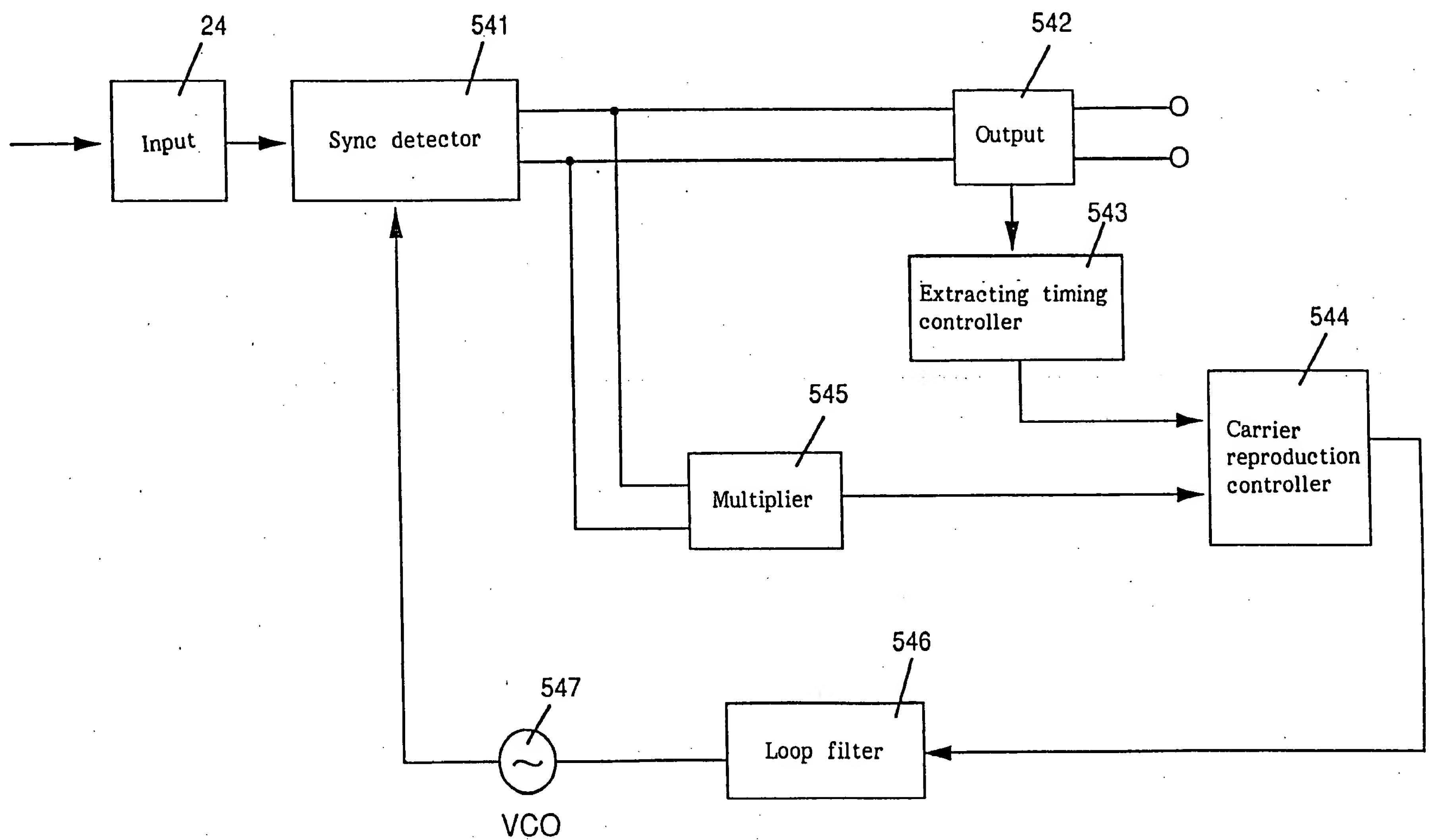


FIG. 43



07.12.92

FIG. 44

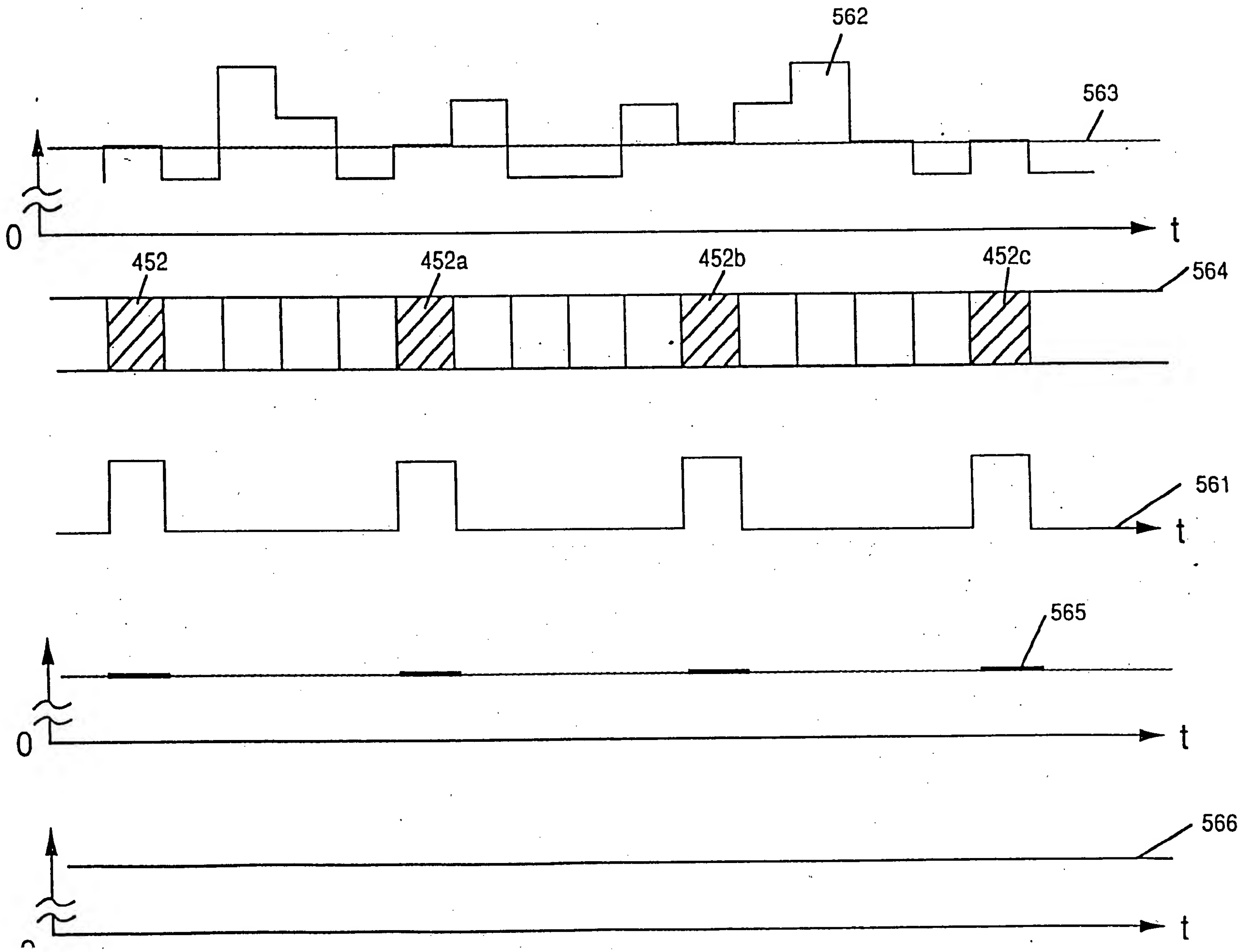
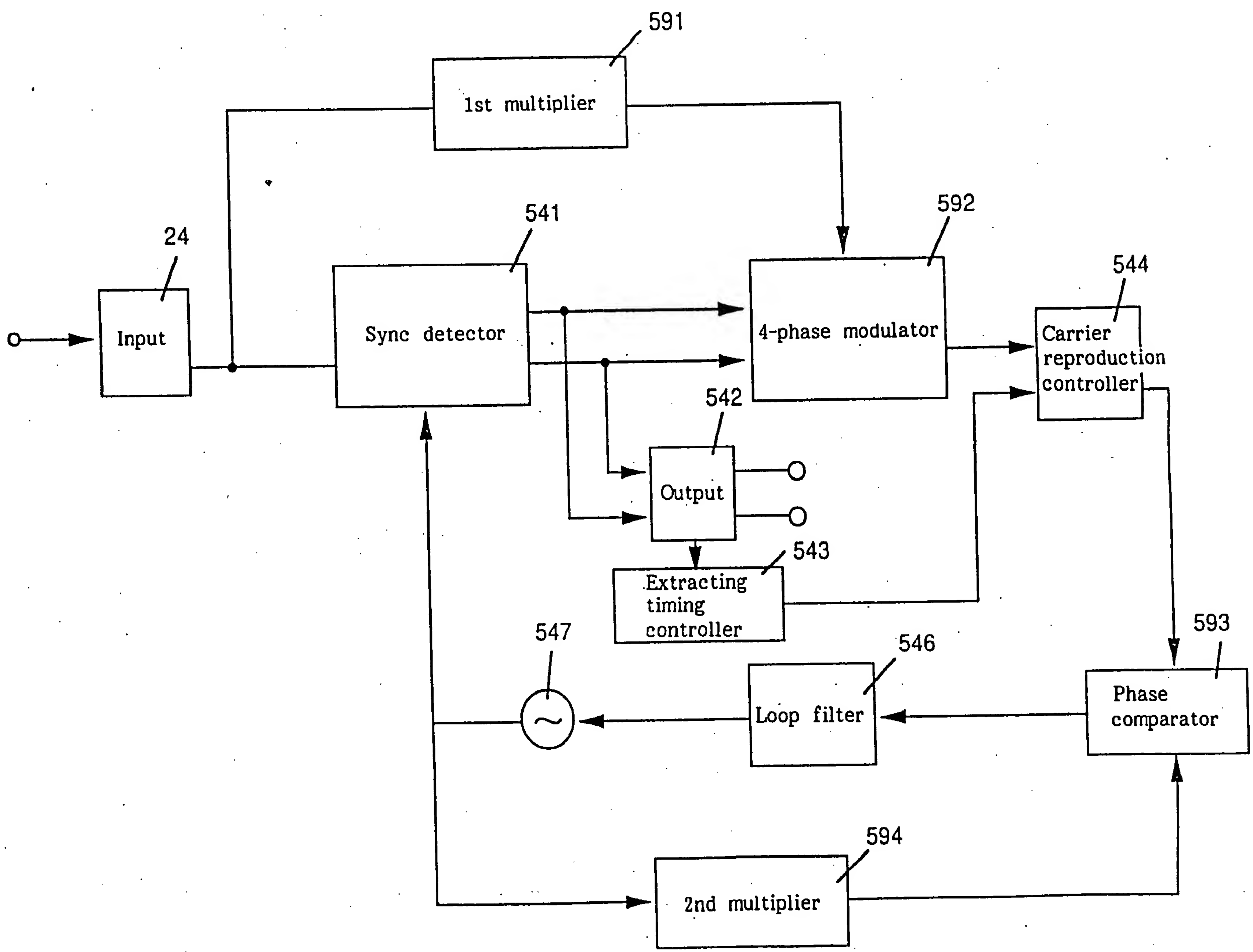
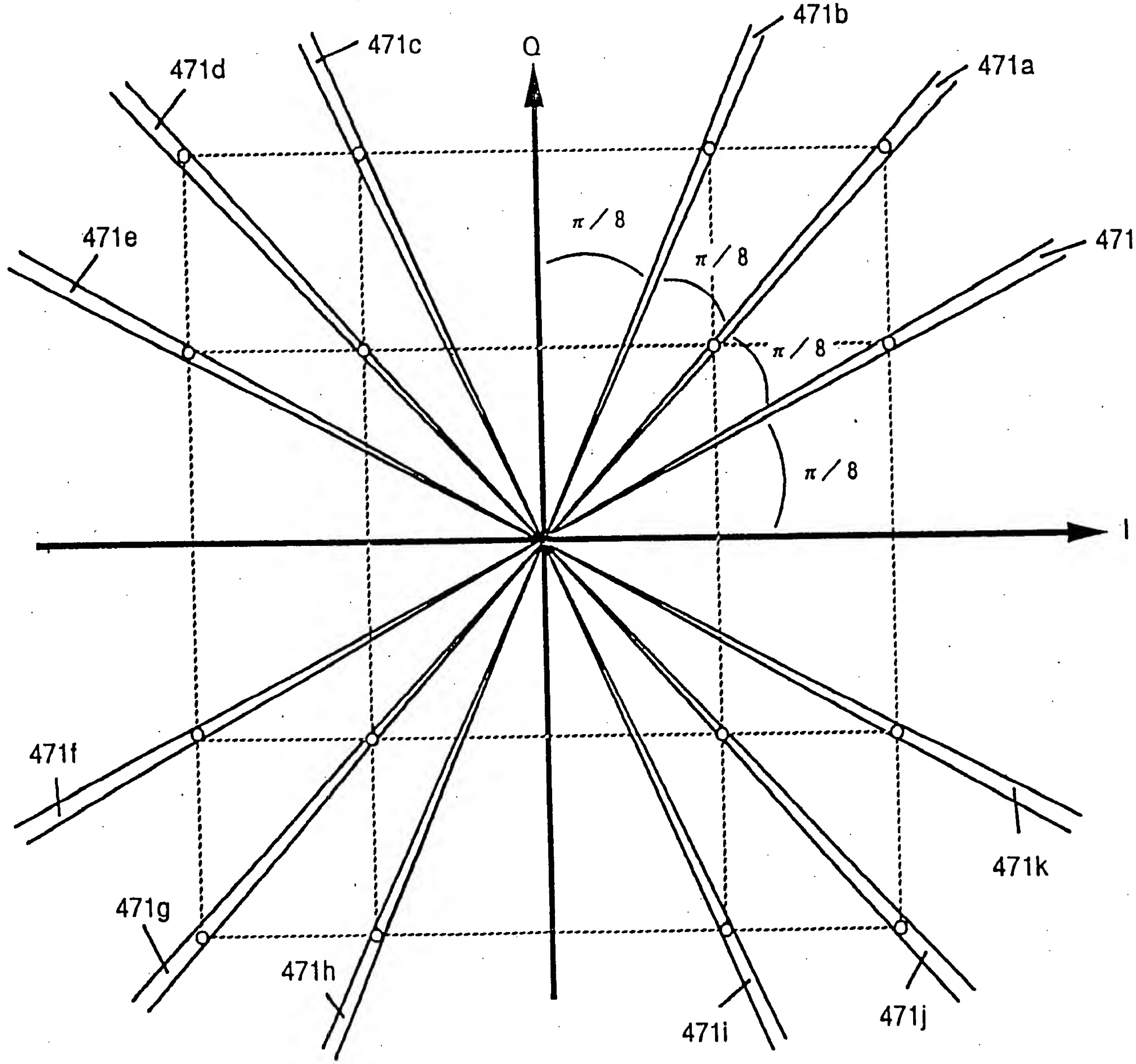


FIG. 45



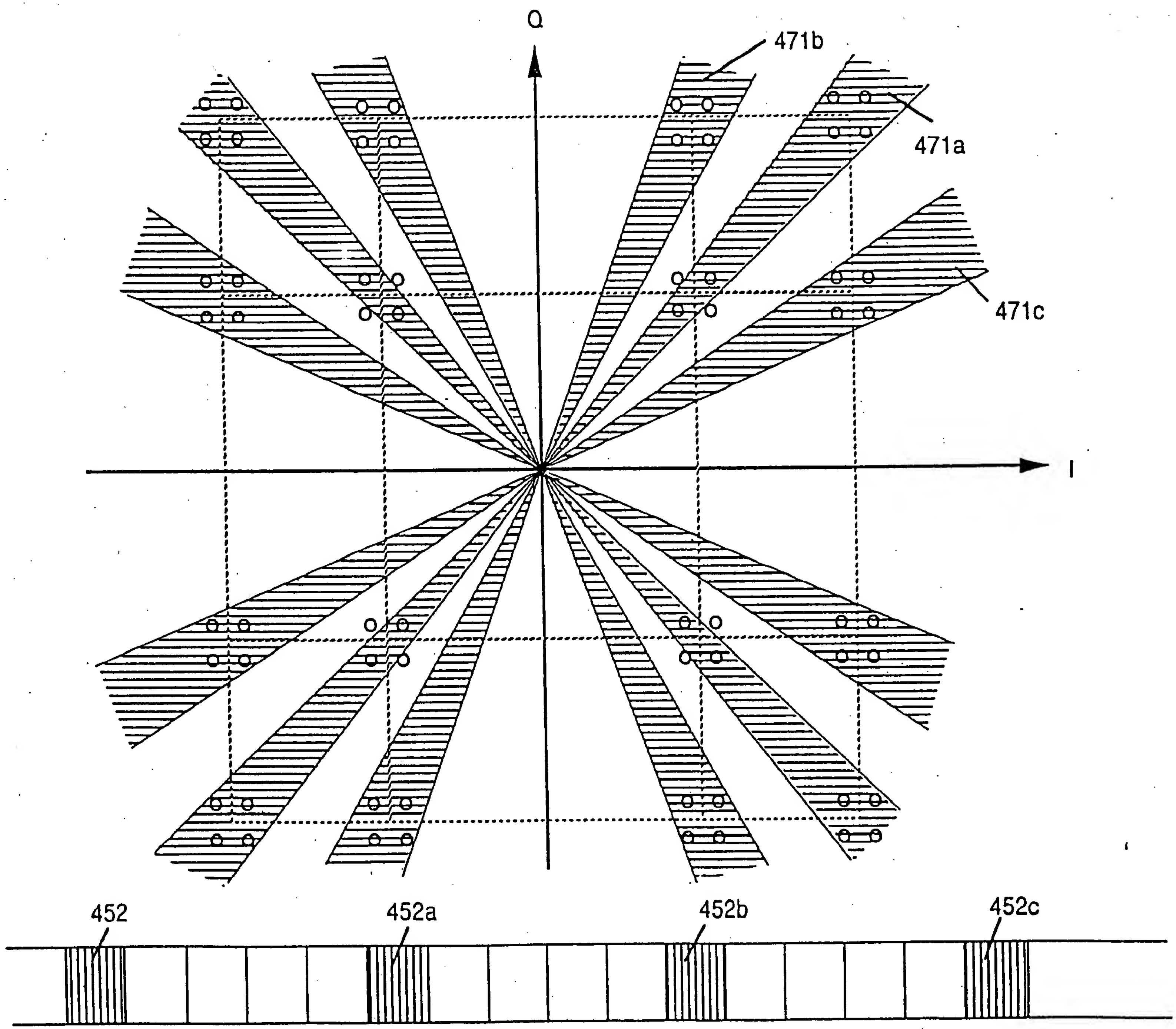
07.12.93

FIG. 46



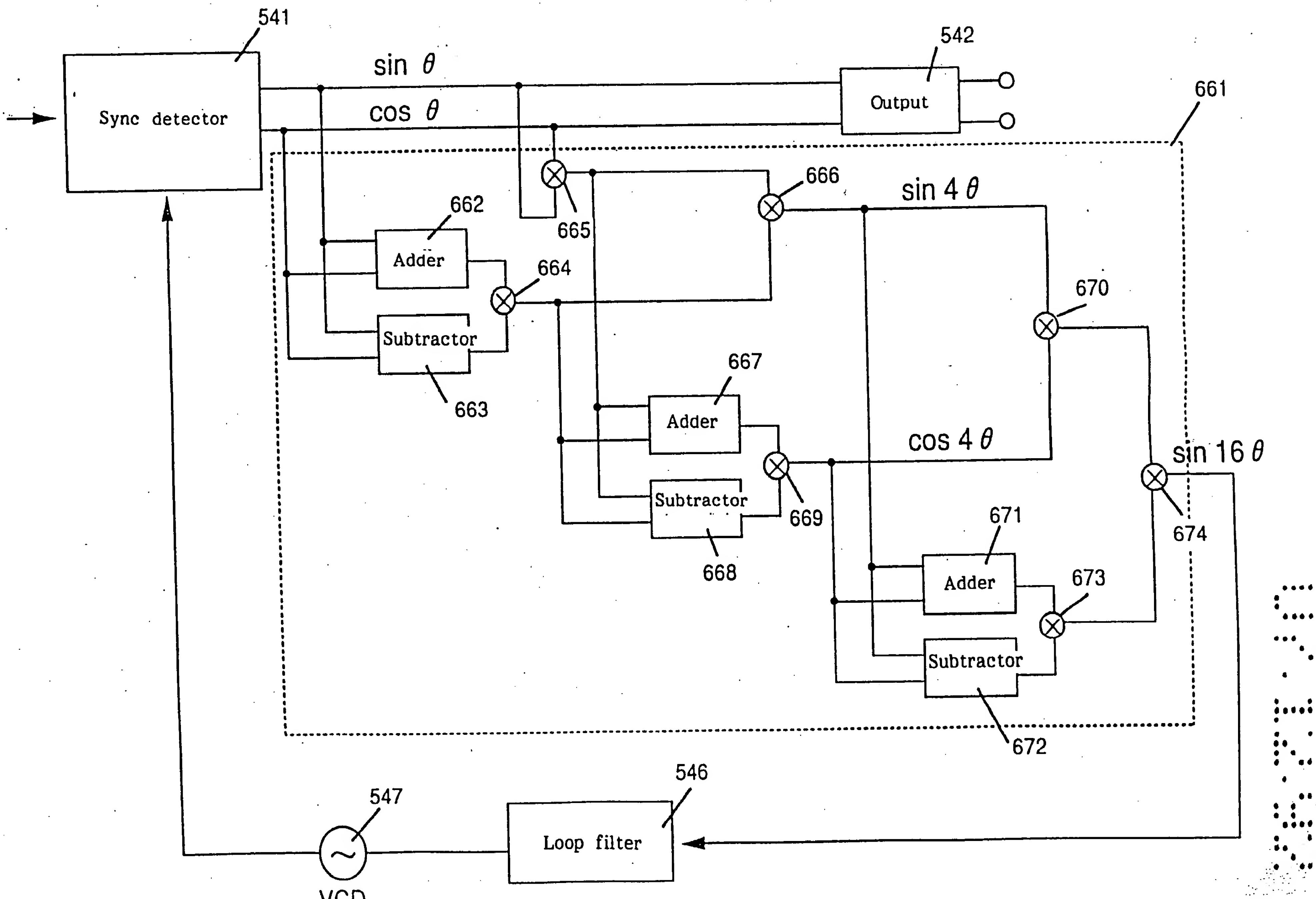
07.12.97

FIG. 47



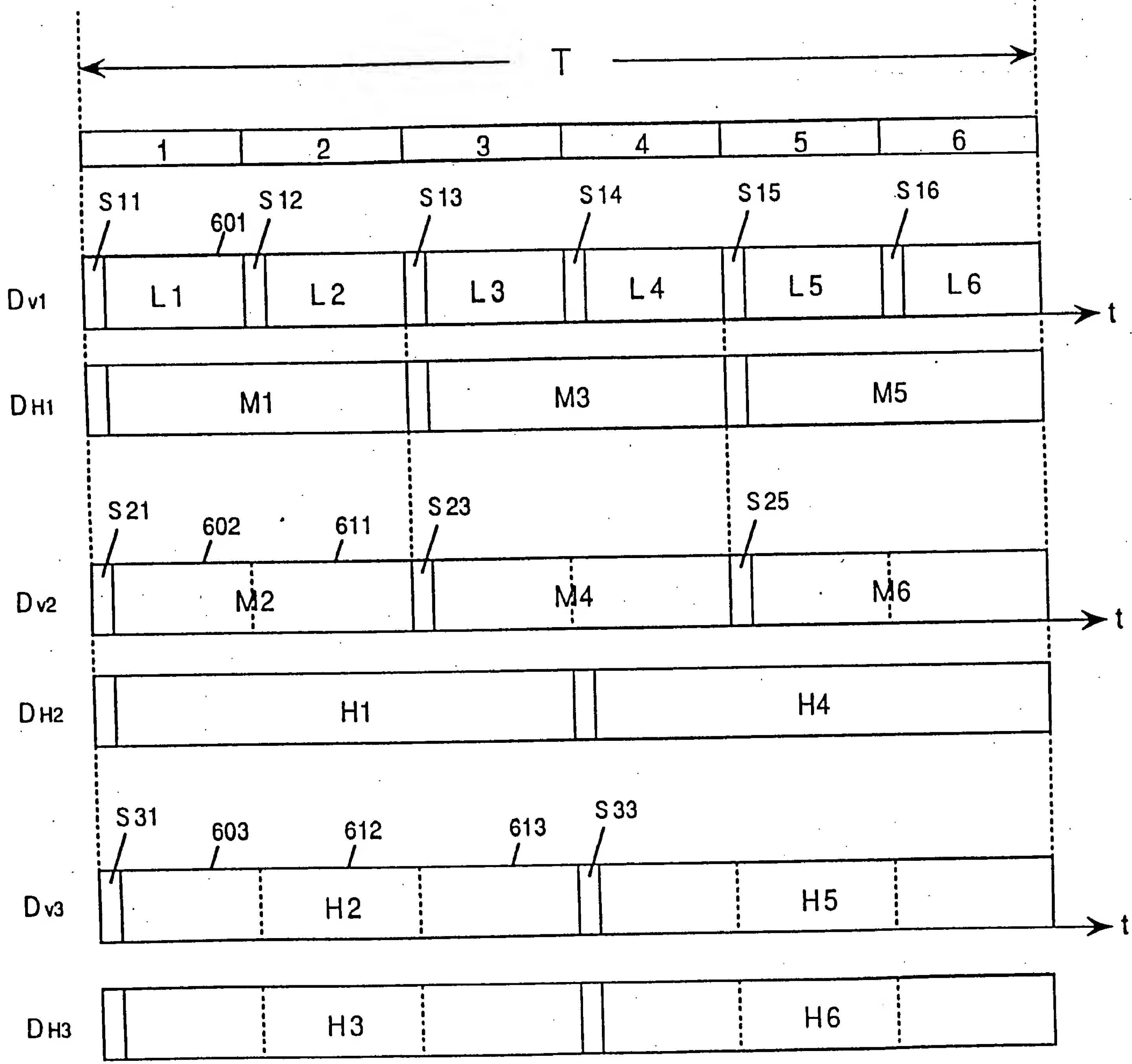
07.12.97

FIG. 48



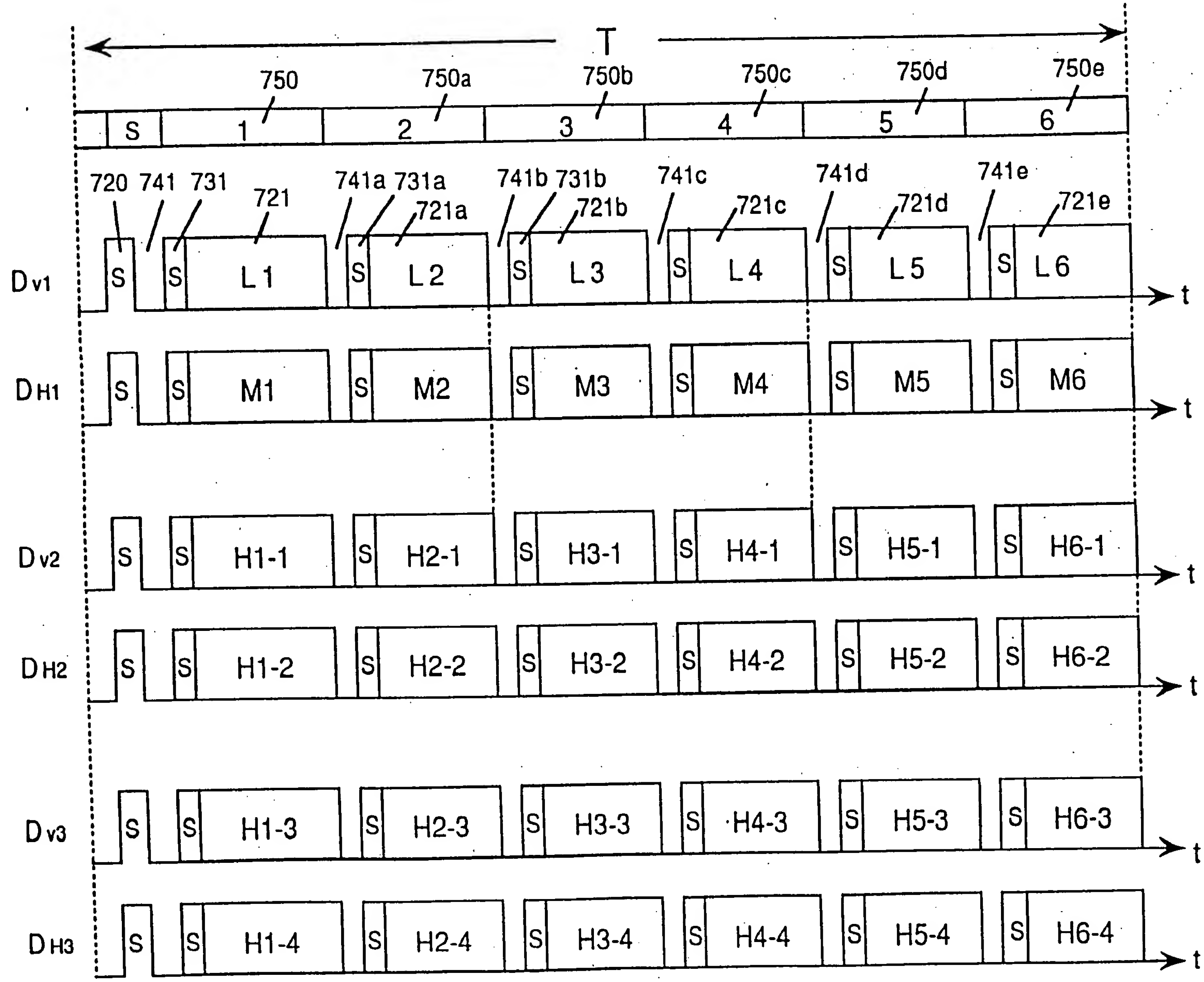
541
Sync detector
sin θ
cos θ
542
Output
661
662
Adder
663
Subtractor
664
665
666
sin 4 θ
667
Adder
668
Subtractor
669
cos 4 θ
670
671
Adder
672
Subtractor
673
674
sin 16 θ
546
Loop filter
547

FIG. 49



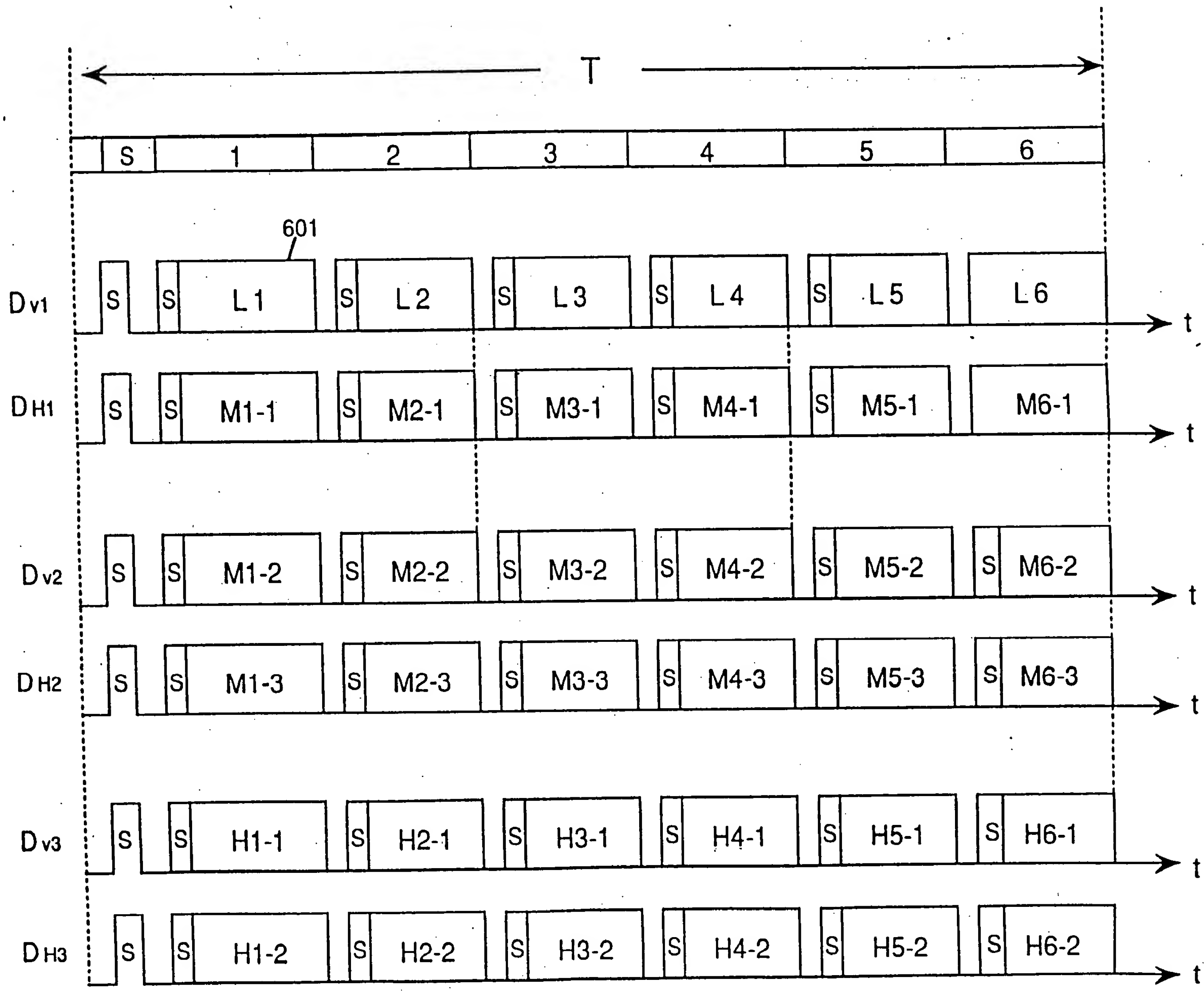
T
1
2
3
4
5
6
S11
601
S12
S13
S14
S15
S16
Dv1
L1
L2
L3
L4
L5
L6
t
DH1
M1
M3
M5
S21
602
611
S23
S25
Dv2
M2
M4
M6
t
DH2
H1
H4
S31
603
612
613
S33
Dv3
H2
H5
t
DH3
H3
H6

FIG.50



07.12.92

FIG. 51



07.12.93

FIG.52

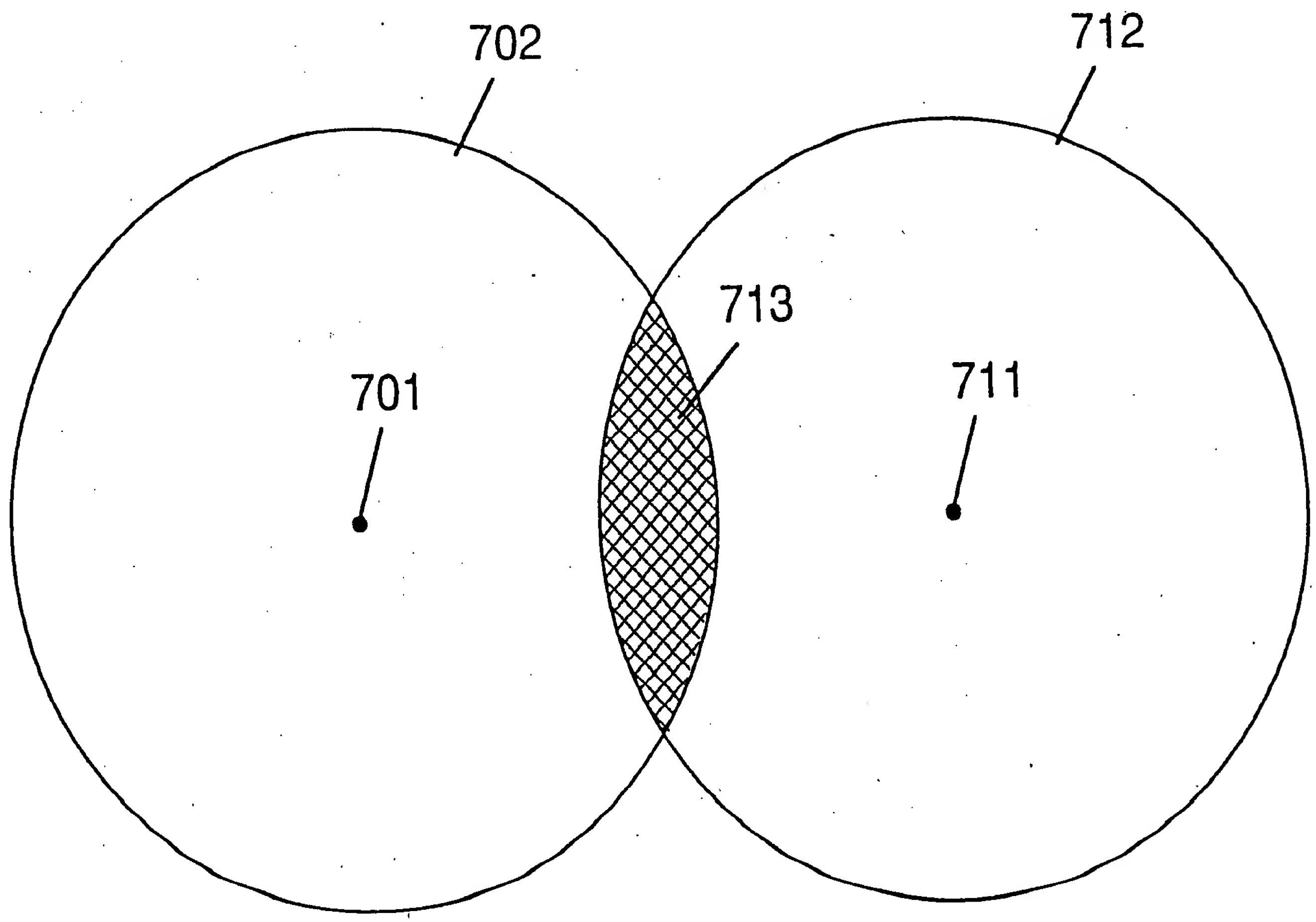
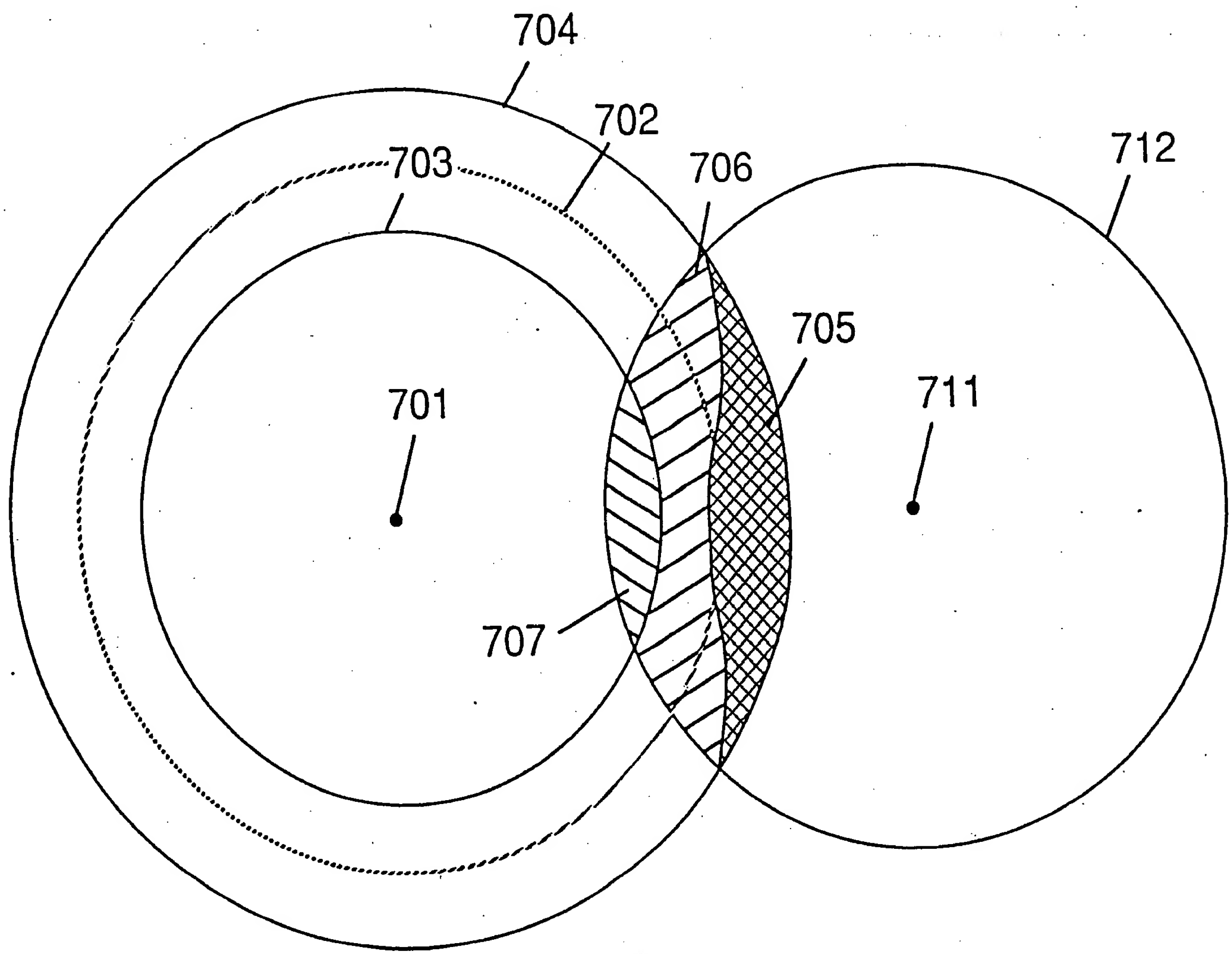
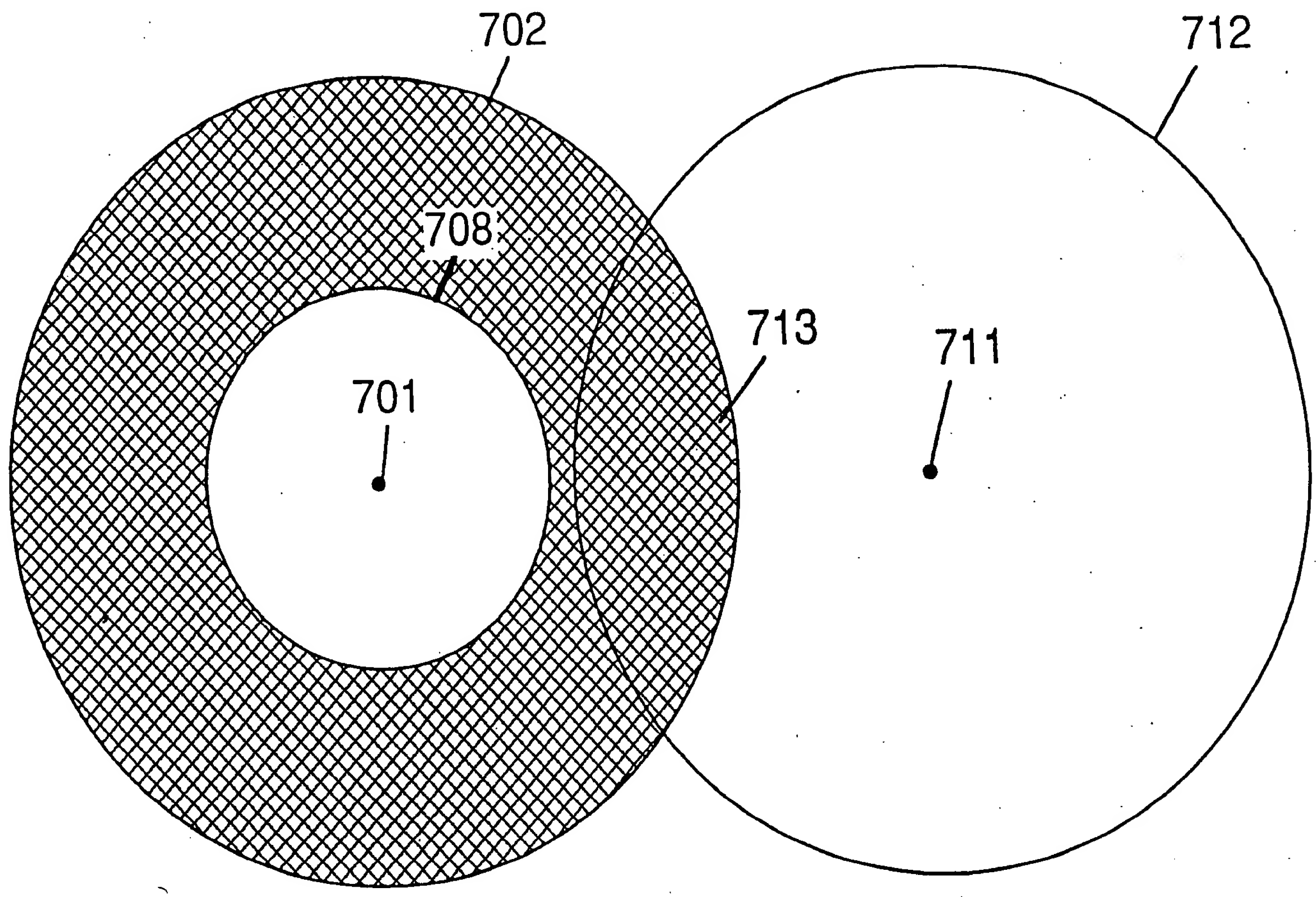


FIG.53



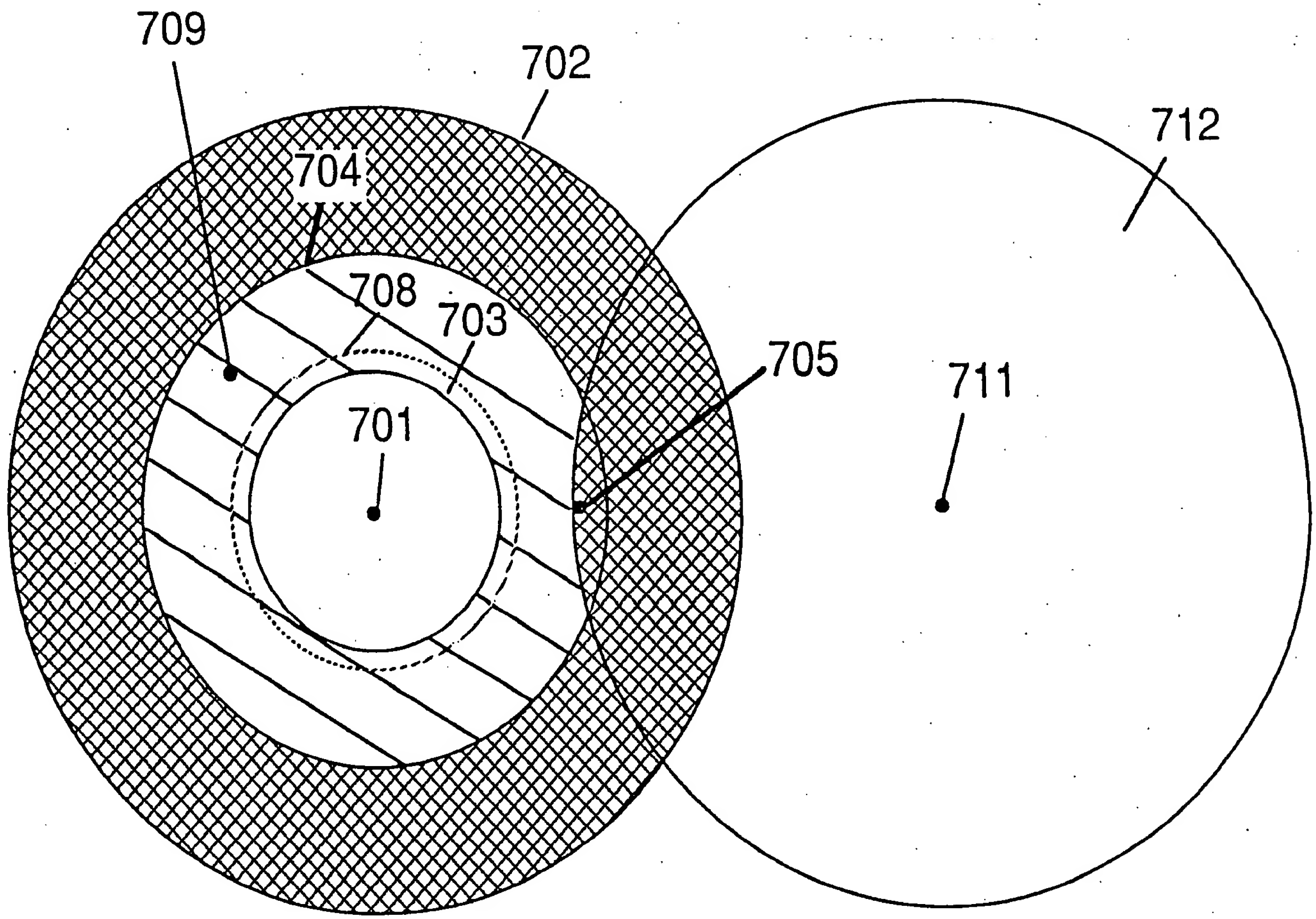
07.12.92

FIG. 54



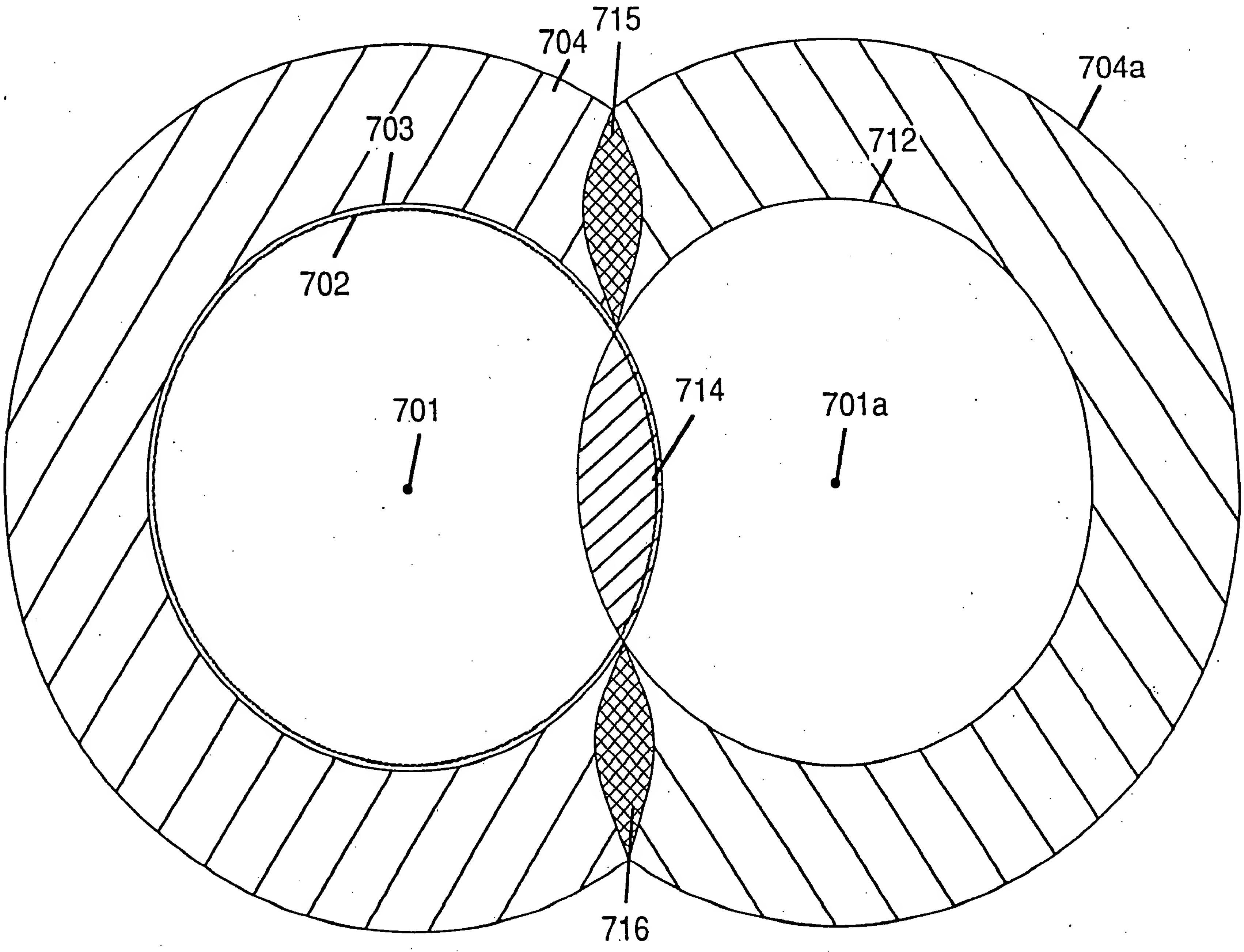
07.12.97

FIG.55



07.12.92

FIG.56



07.12.97

FIG.57

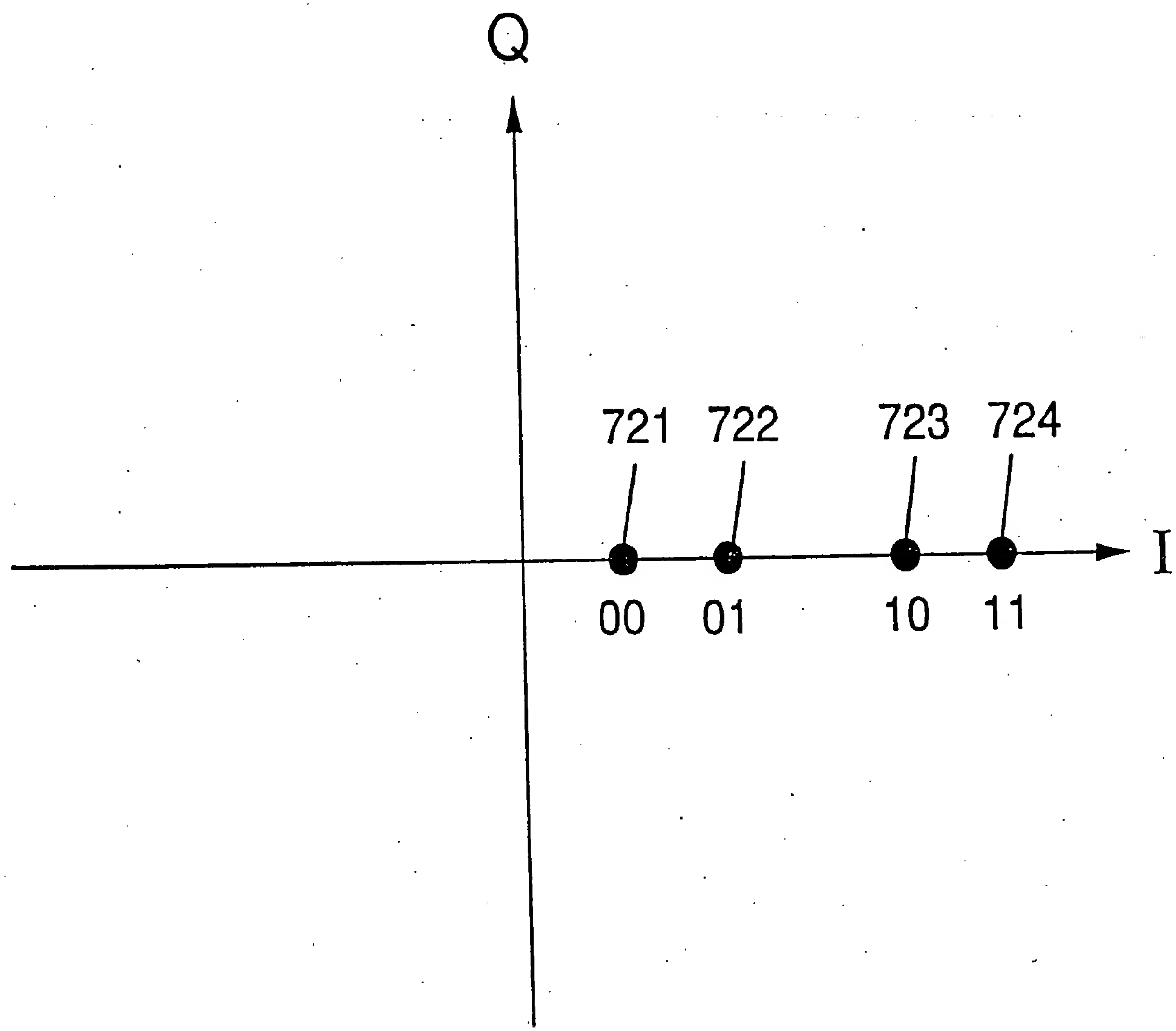
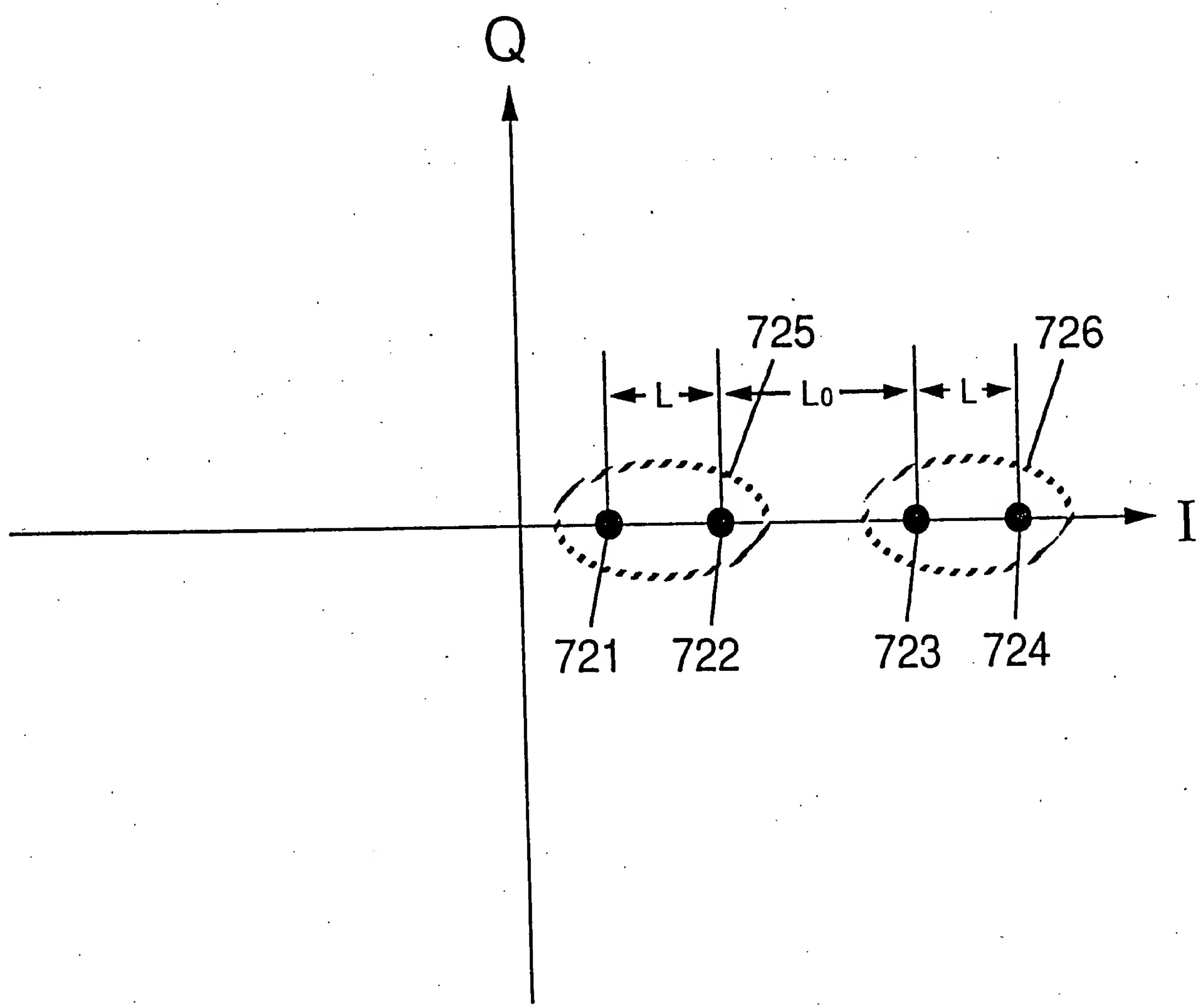
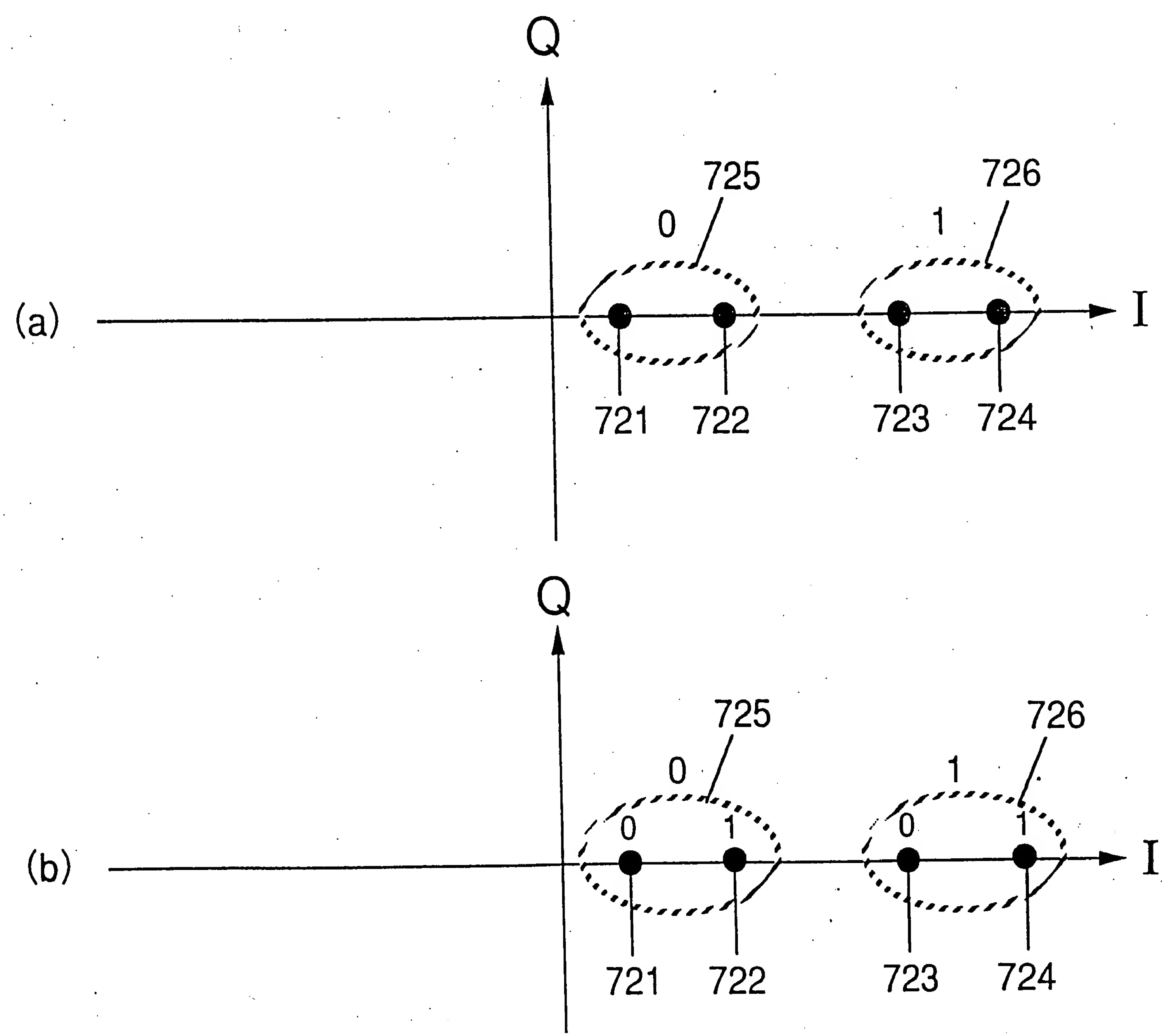


FIG.58



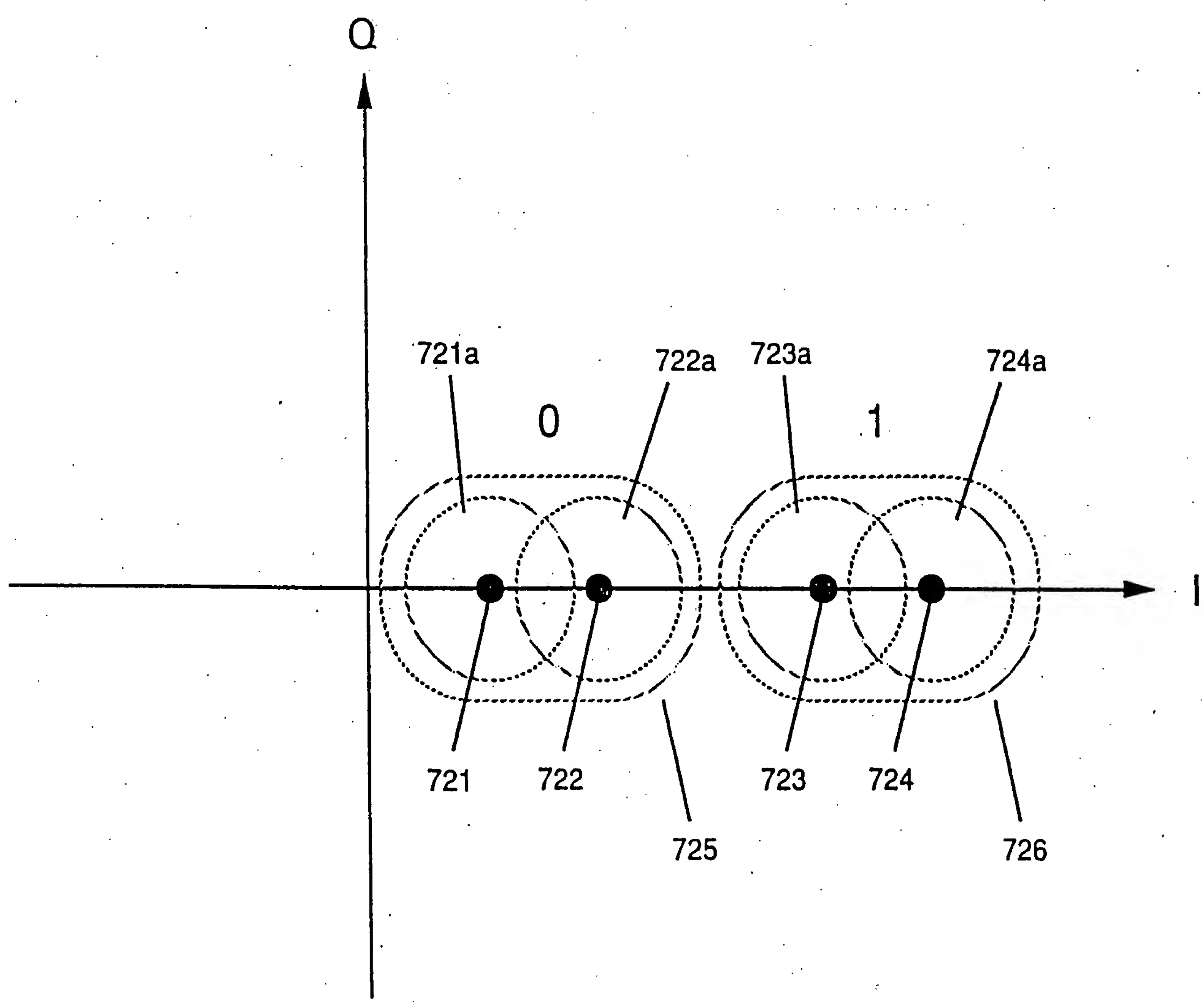
07.12.92

FIG.59



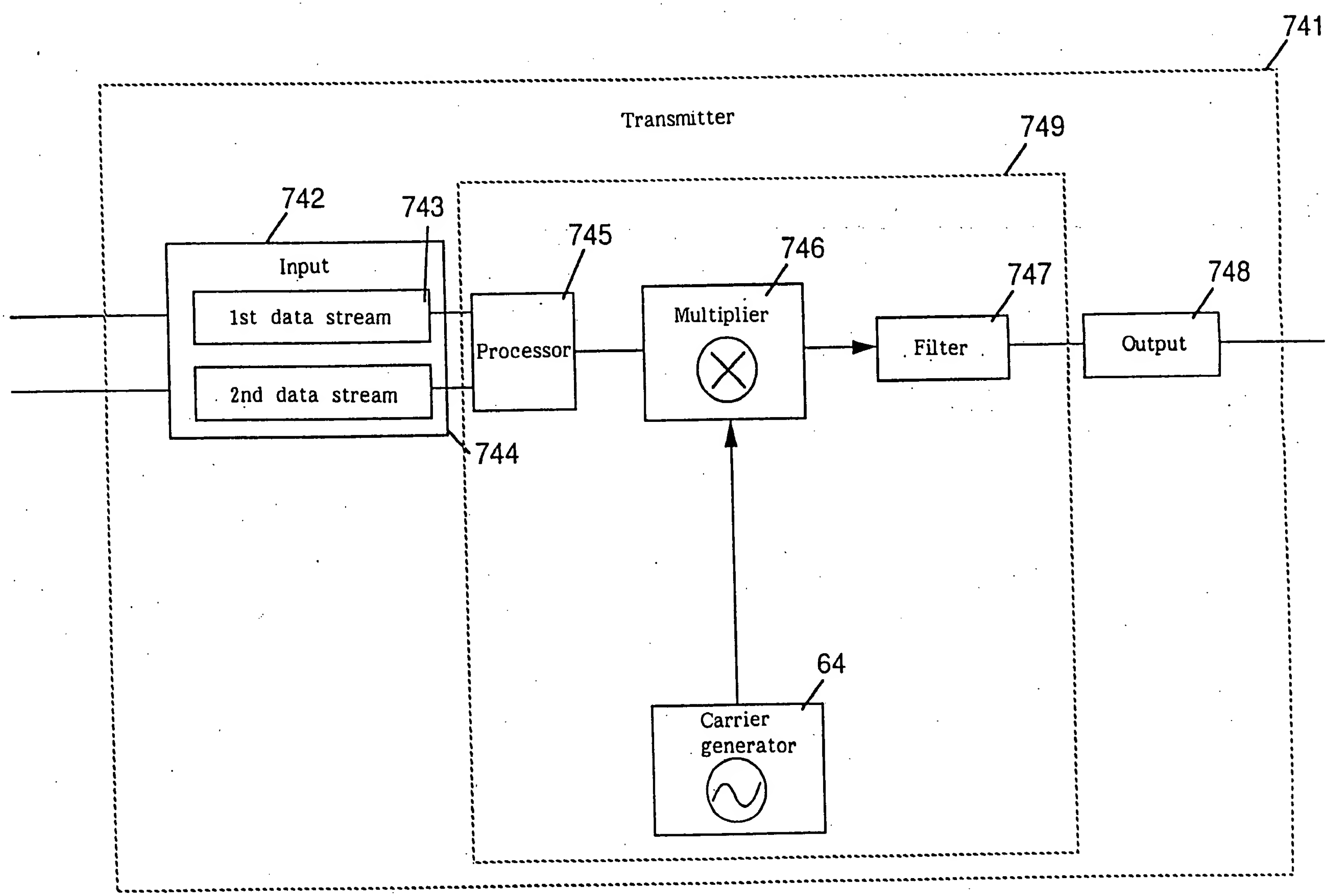
07.12.97

FIG.60



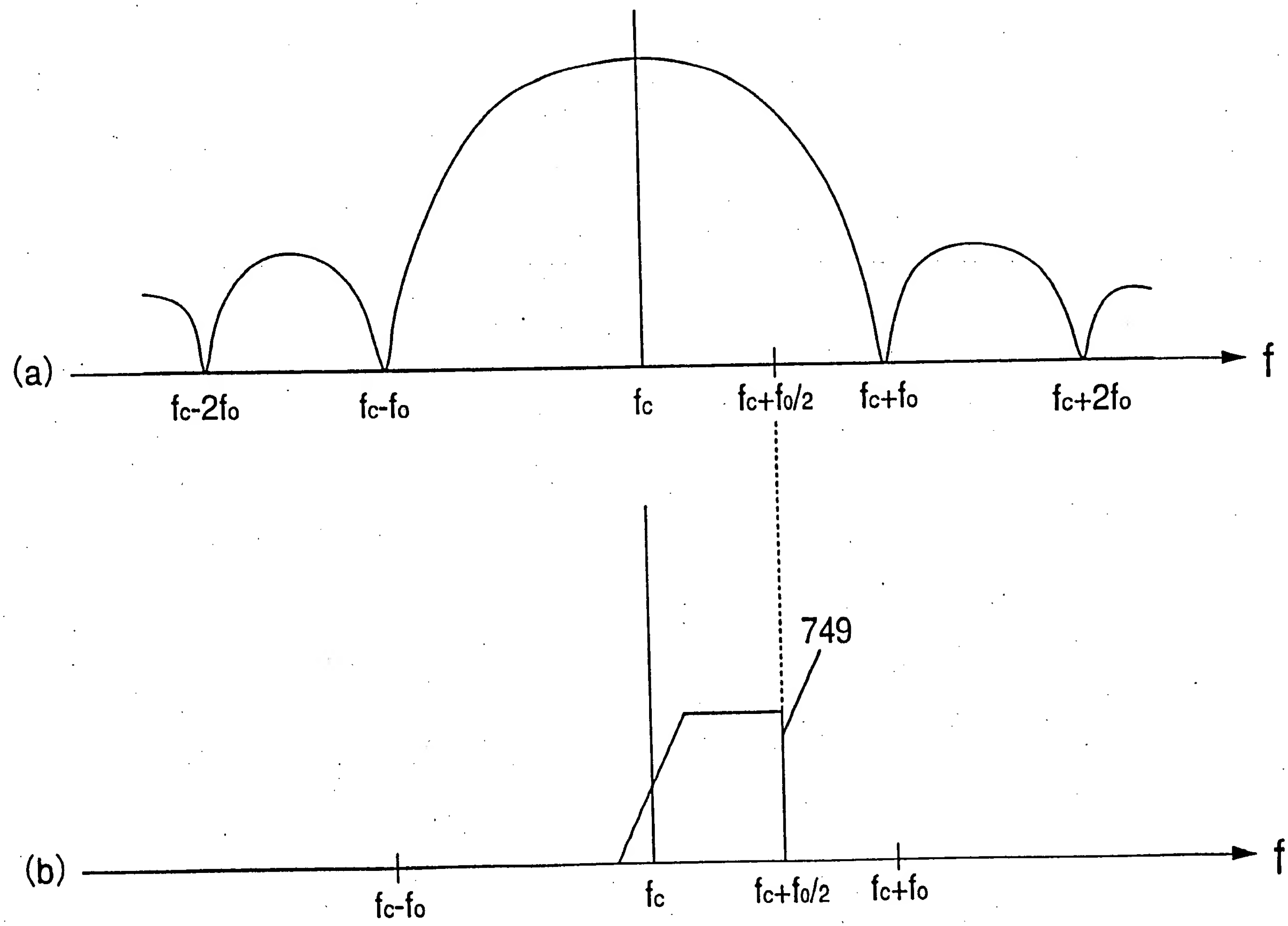
07.12.92

FIG. 61



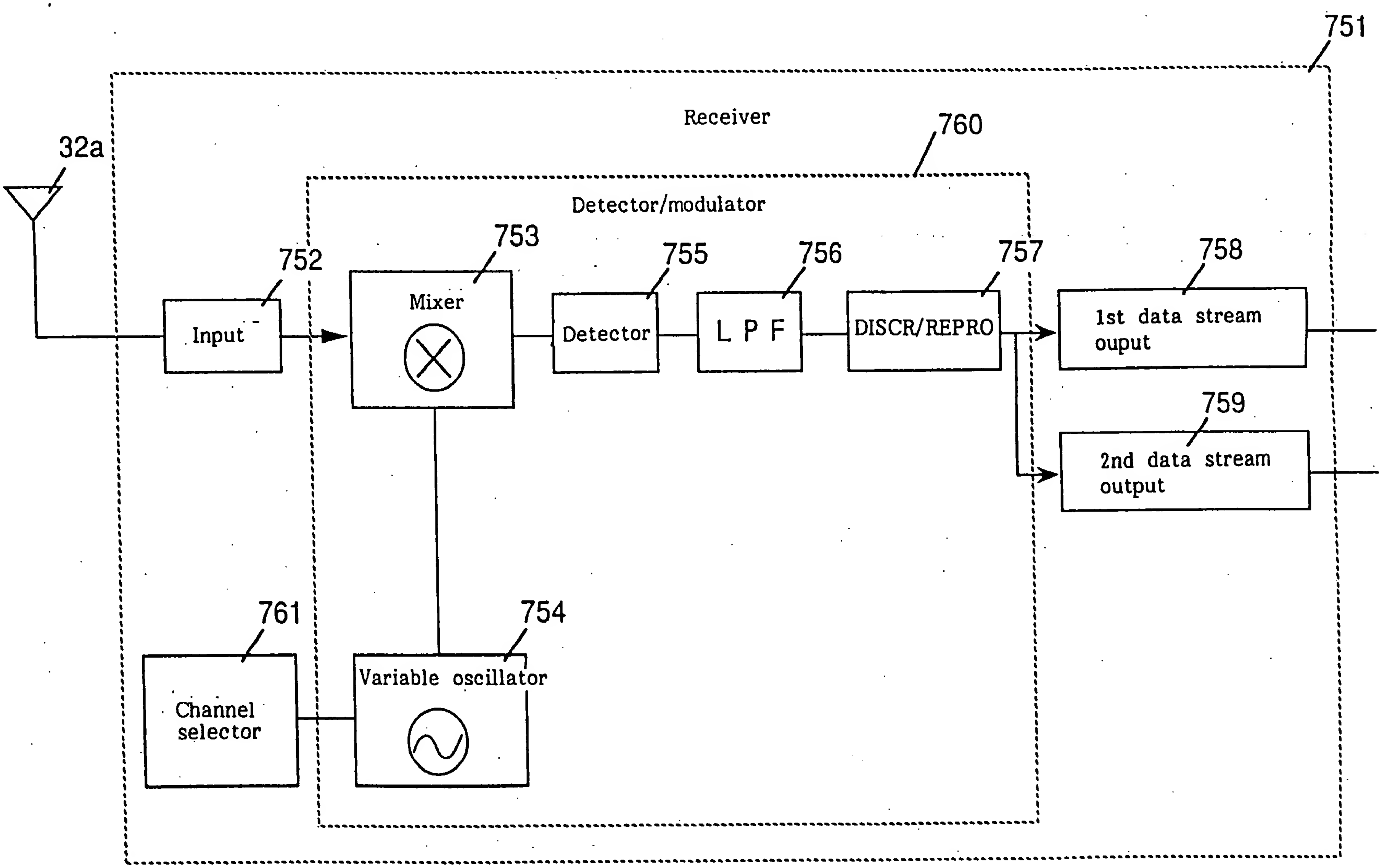
07.12.92

FIG.62



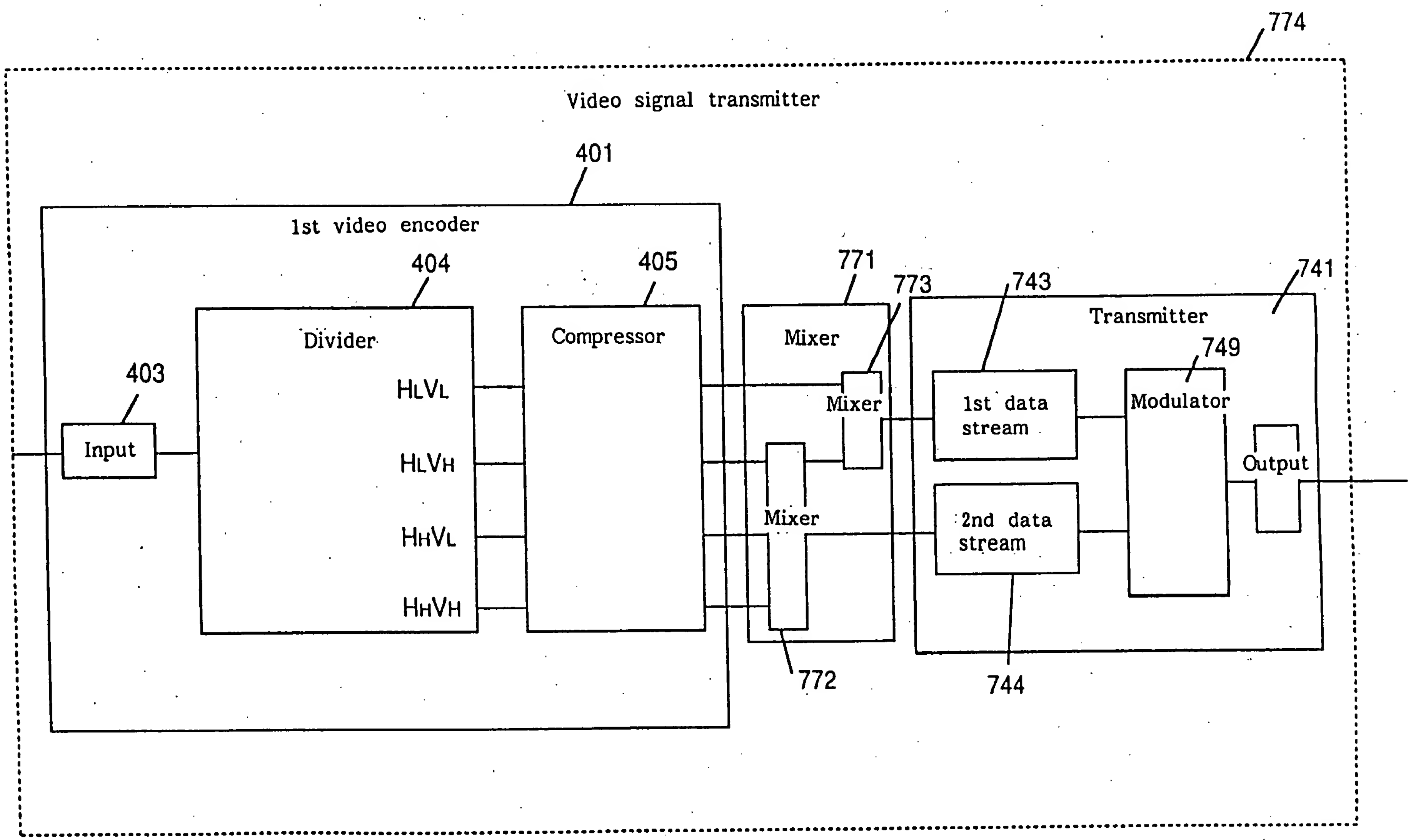
07.12.97

FIG.63



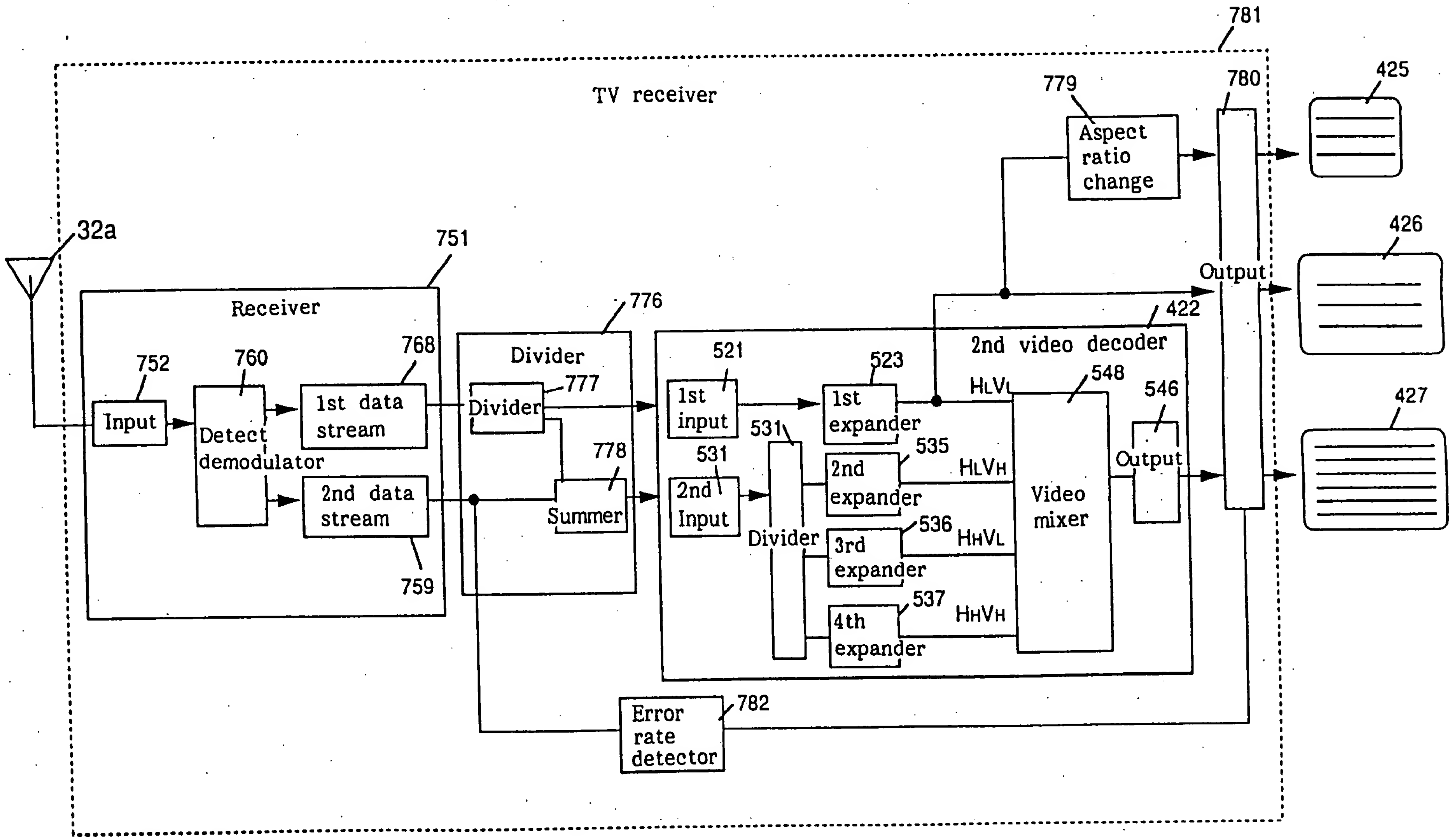
07.12.92

FIG. 64



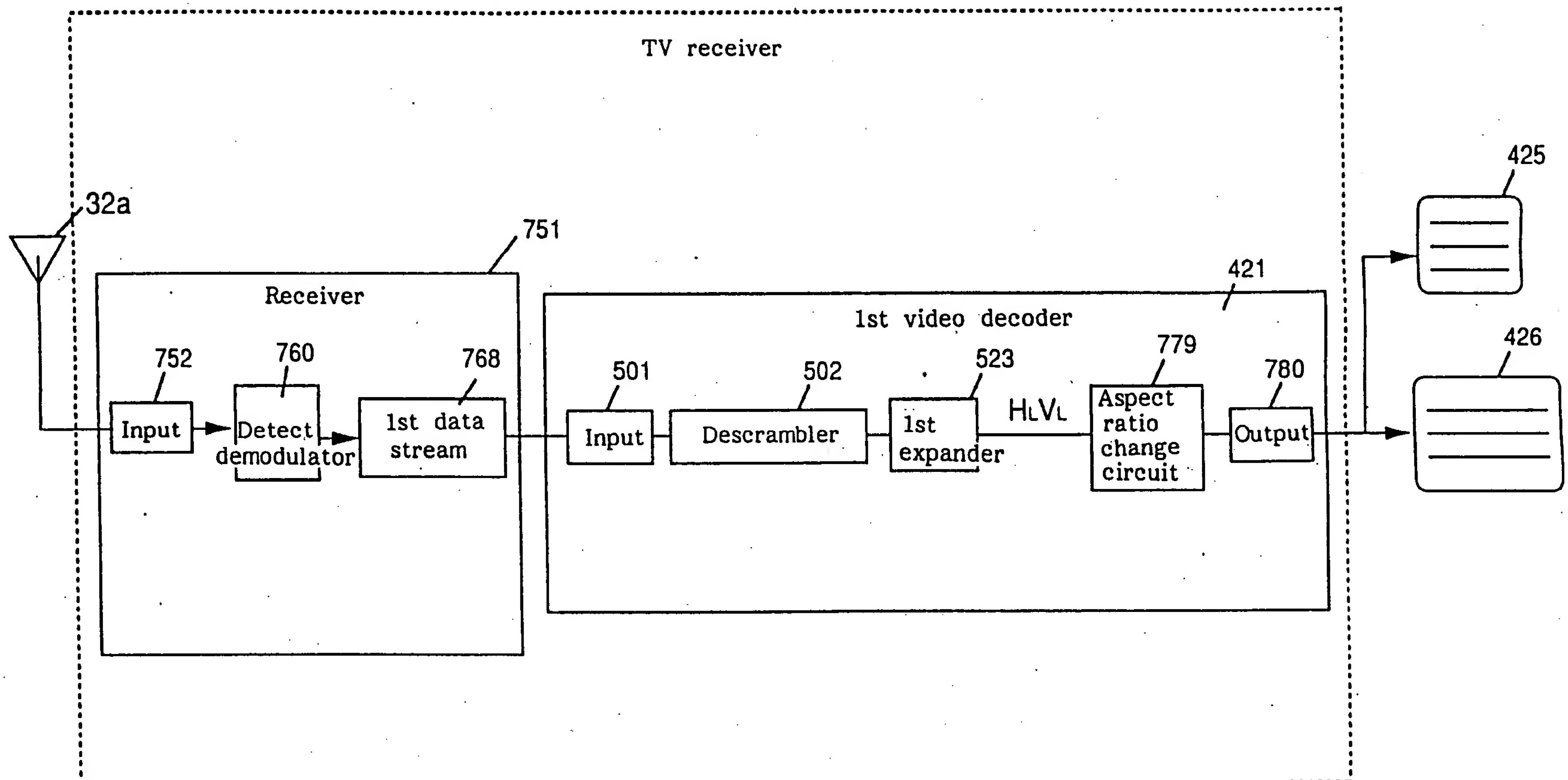
07.12.92

FIG.65



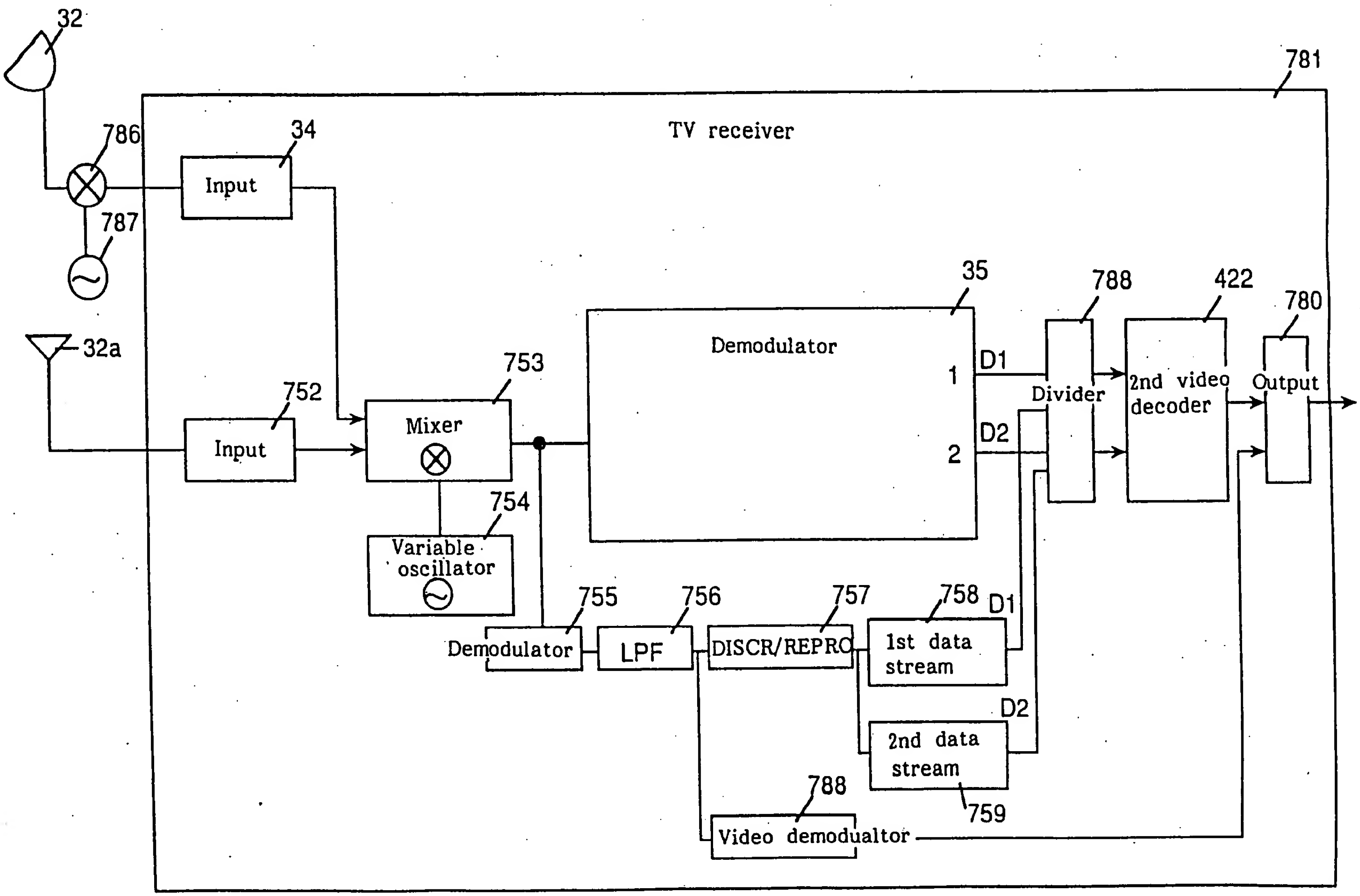
07.12.92

FIG.66



07.12.92

FIG. 67



07.12.92

FIG.68

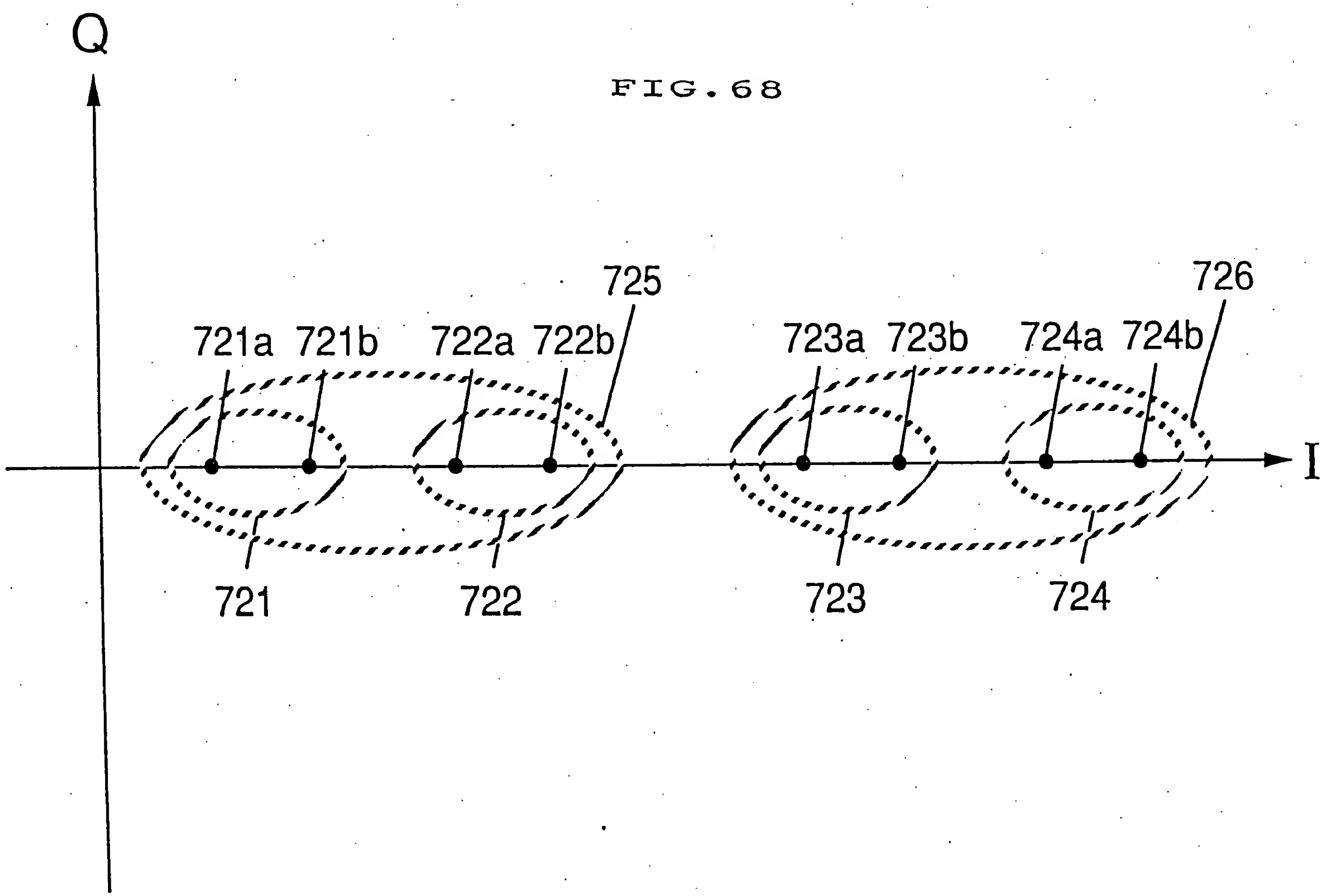
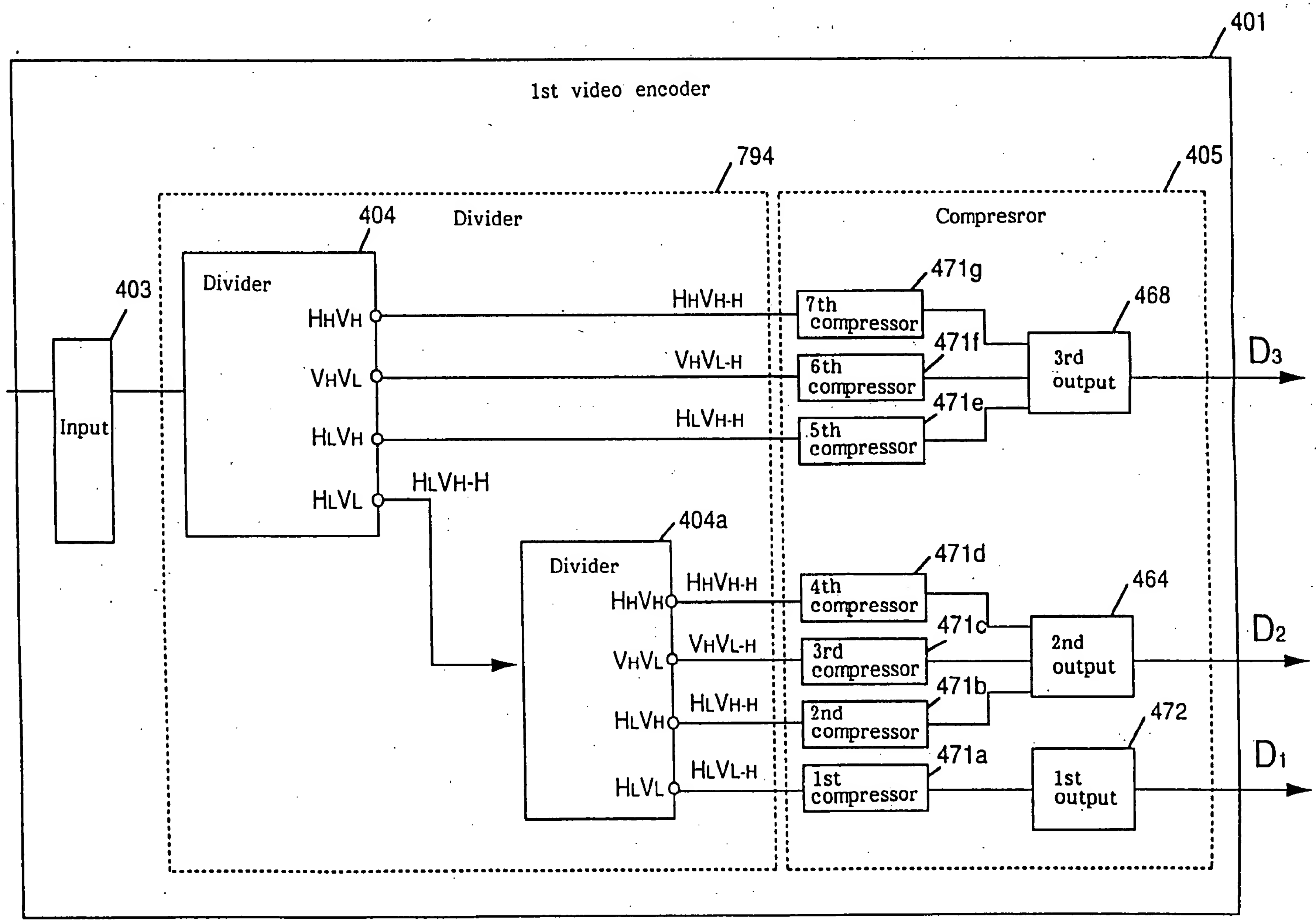
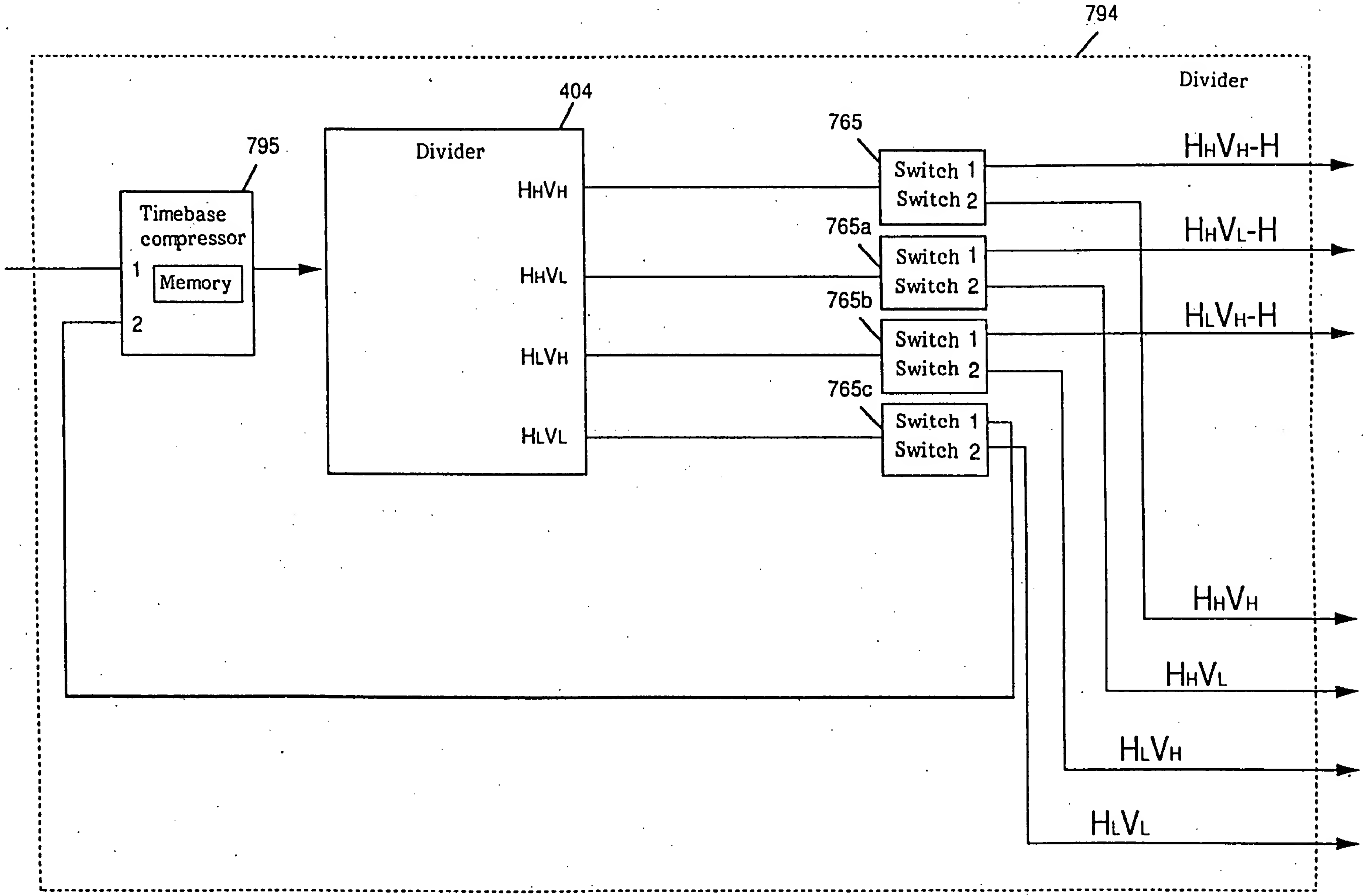

Q
I
721a 721b 722a 722b
725
723a 723b 724a 724b
726
721
722
723
724

FIG. 69



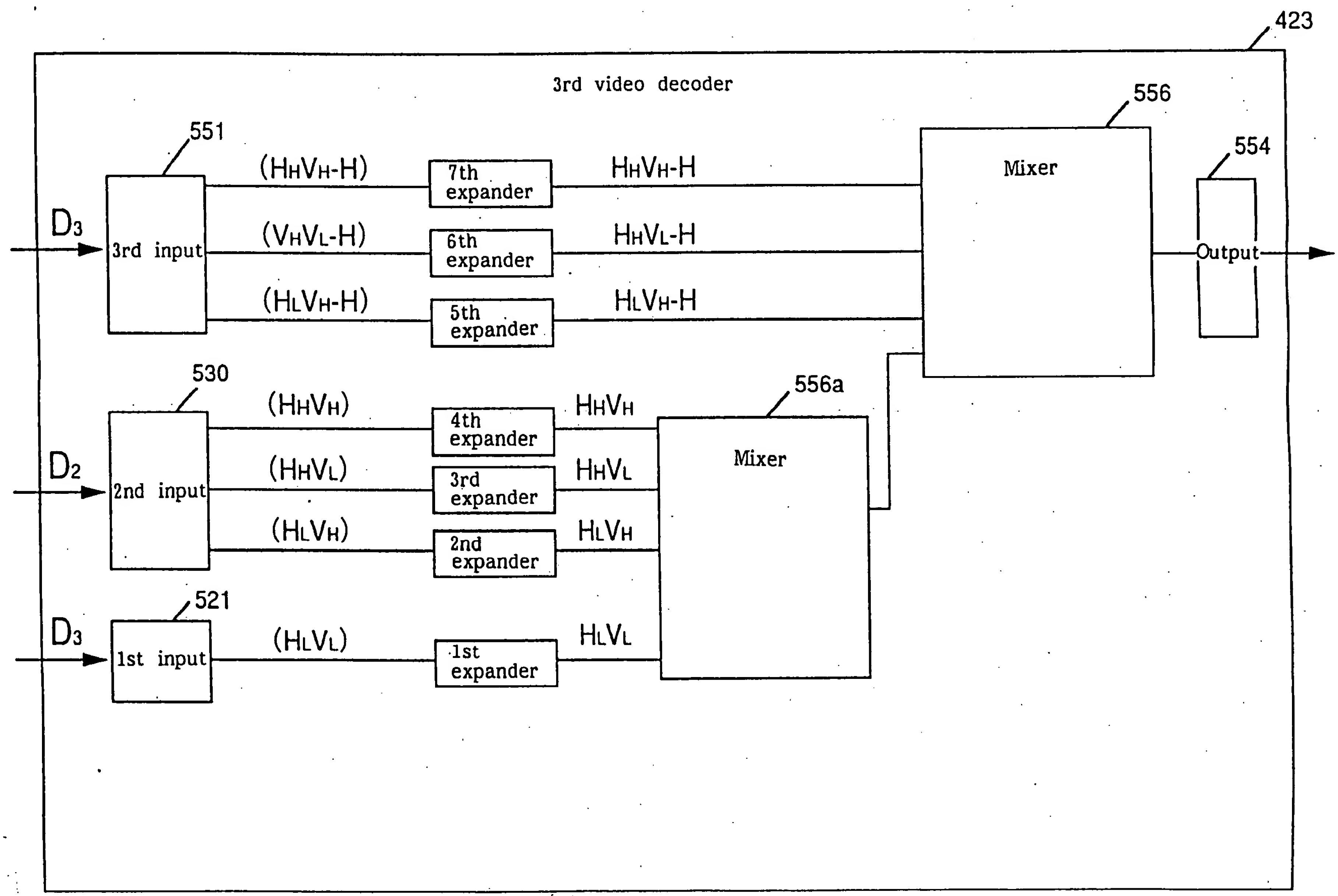
401
1st video encoder
794
405
404
Divider
Compresror
403
Divider
471g
HHVH
HHVH-H
7th compressor
468
471f
VHVL
VHVL-H
6th compressor
3rd output
D3
Input
471e
HLVH
HLVH-H
5th compressor
HLVL
HLVH-H
404a
Divider
471d
HHVH
HHVH-H
4th compressor
464
471c
VHVL
VHVL-H
3rd compressor
2nd output
D2
471b
HLVH
HLVH-H
2nd compressor
472
471a
HLVL
HLVL-H
1st compressor
1st output
D1

FIG. 70



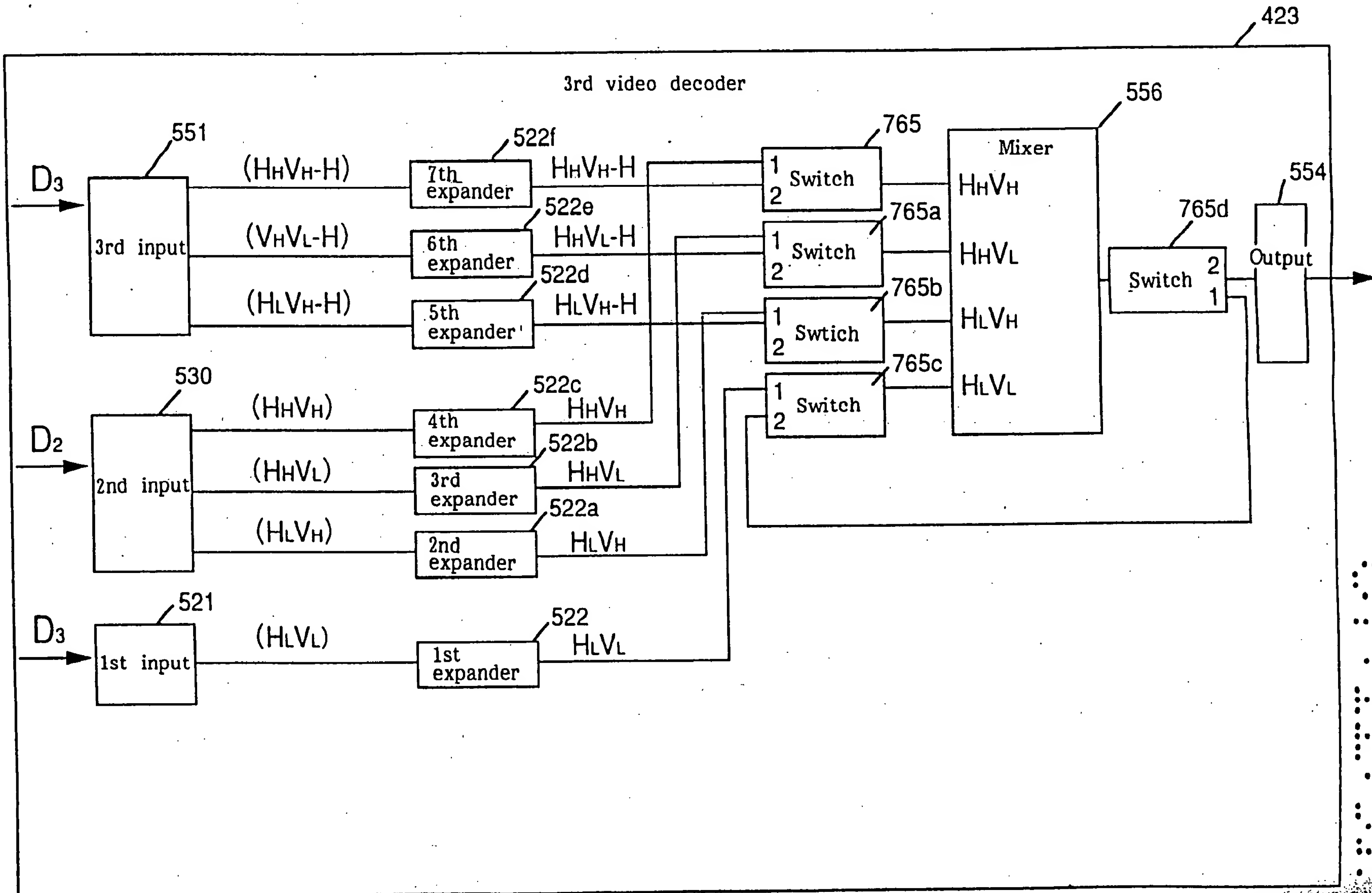
07.12.92

FIG.71



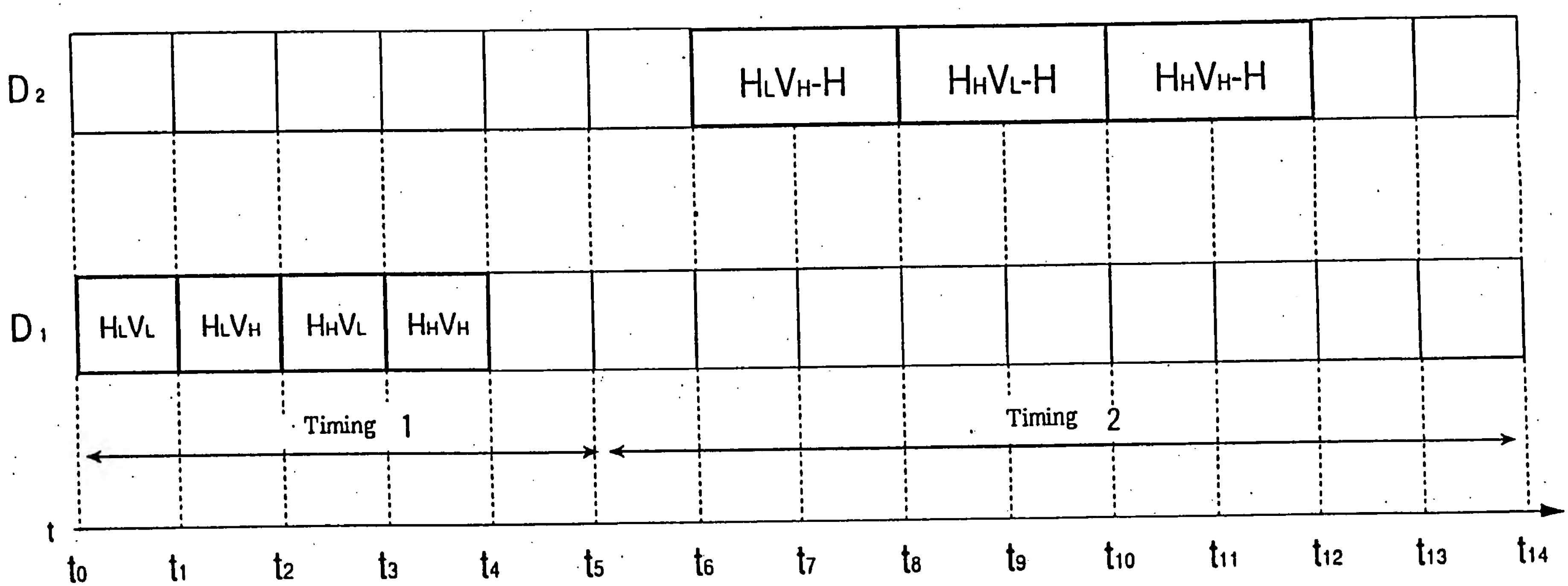
07.12.92

FIG. 72



07.12.92

FIG. 73



D2
HLVH-H
HHVL-H
HHVH-H
D1
HLVL
HLVH
HHVL
HHVH
Timing 1
Timing 2
t
t0
t1
t2
t3
t4
t5
t6
t7
t8
t9
t10
t11
t12
t13
t14

07.12.97

FIG. 74

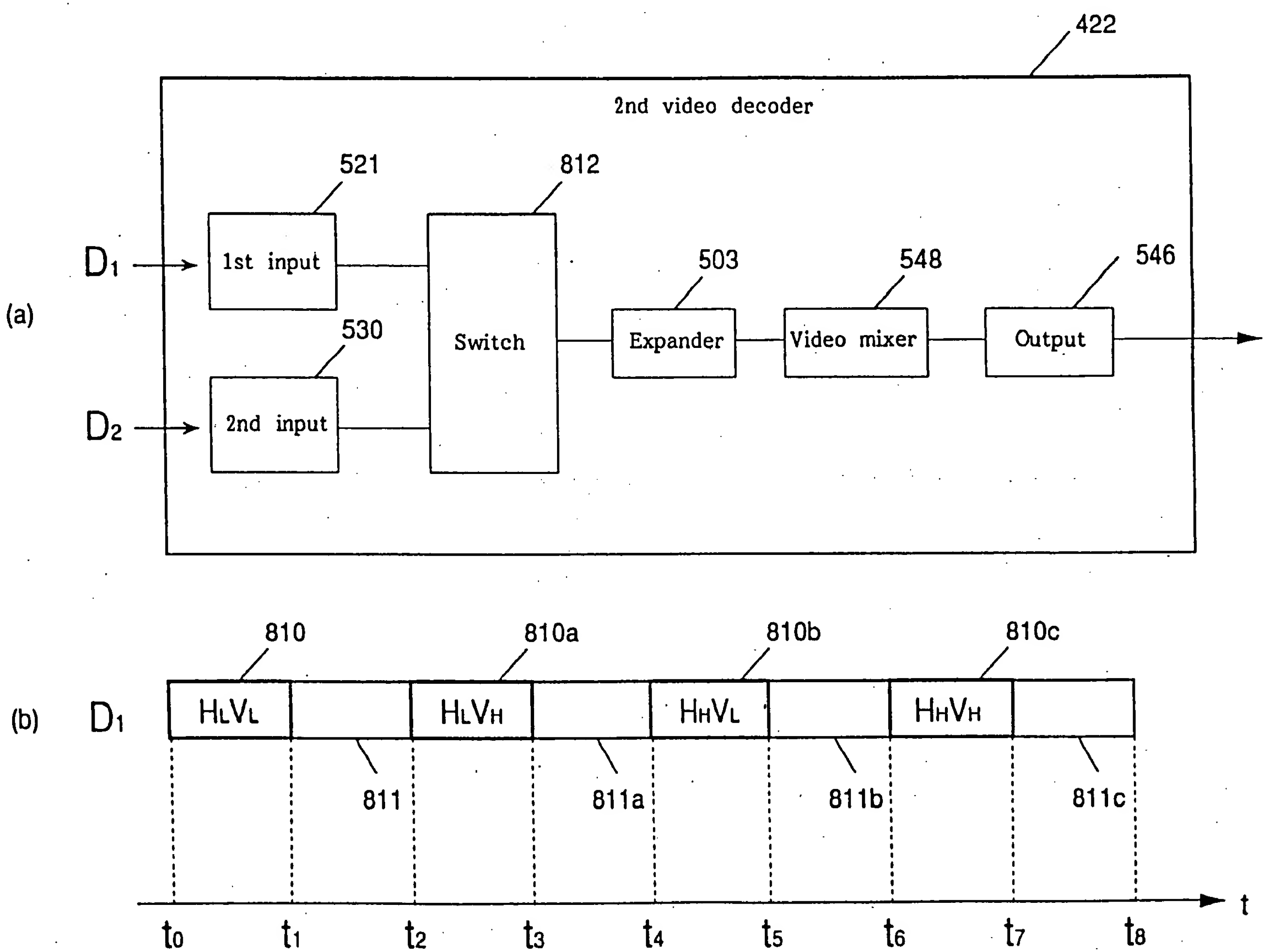
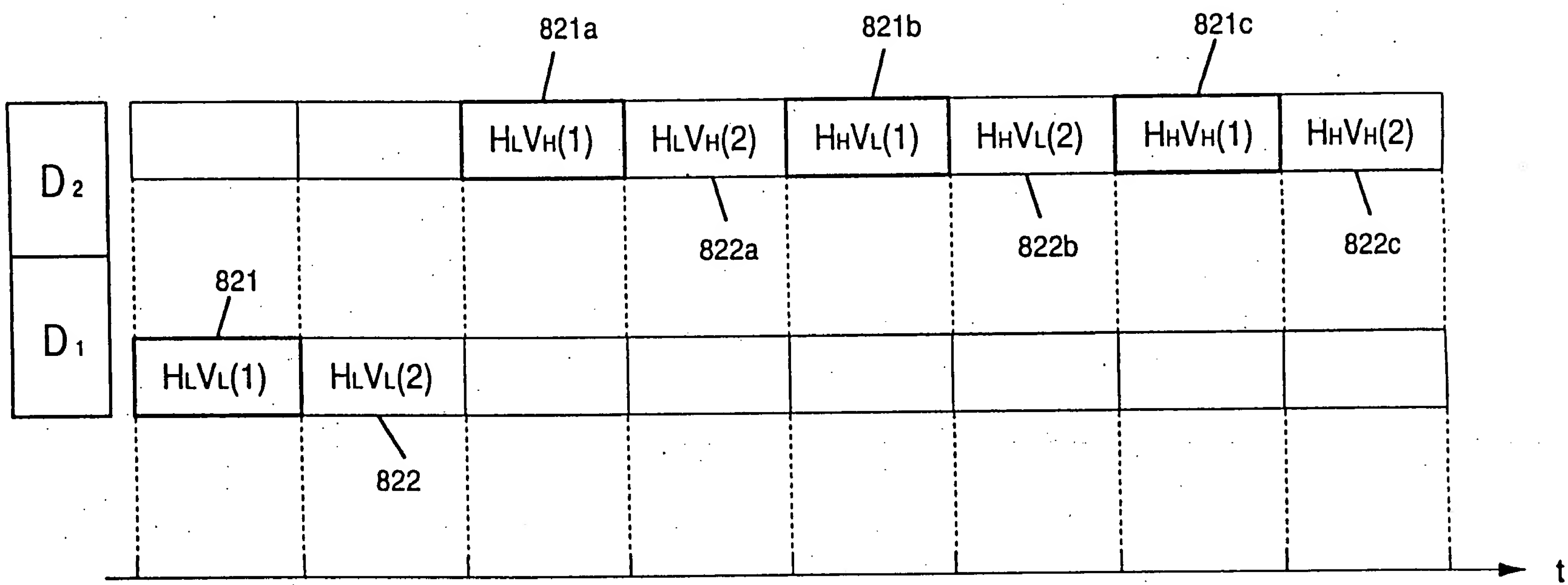


FIG. 75



07.12.92

FIG. 76

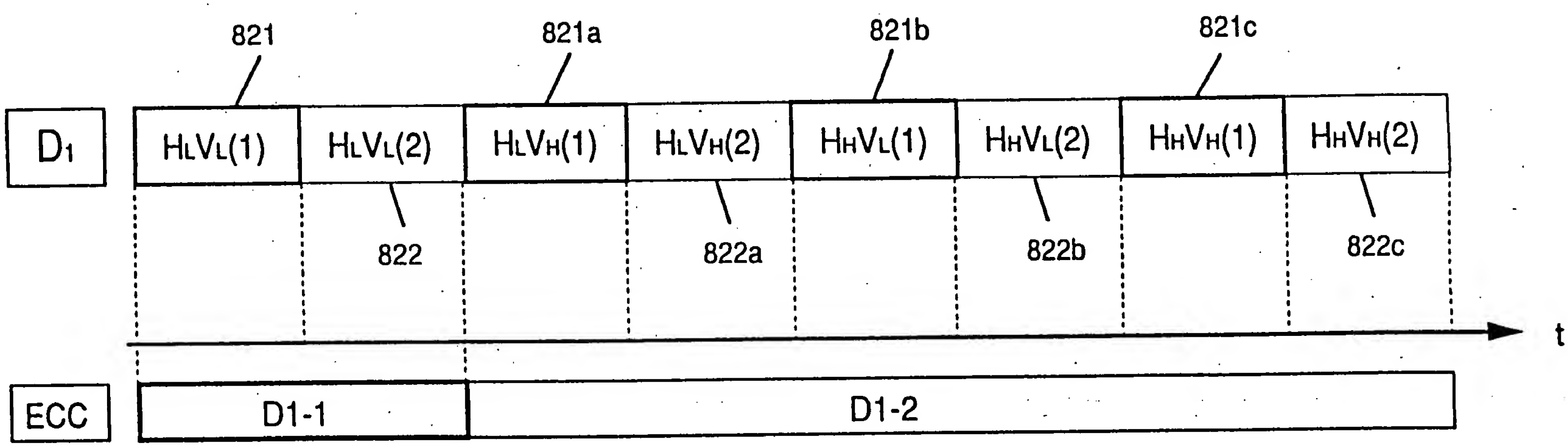


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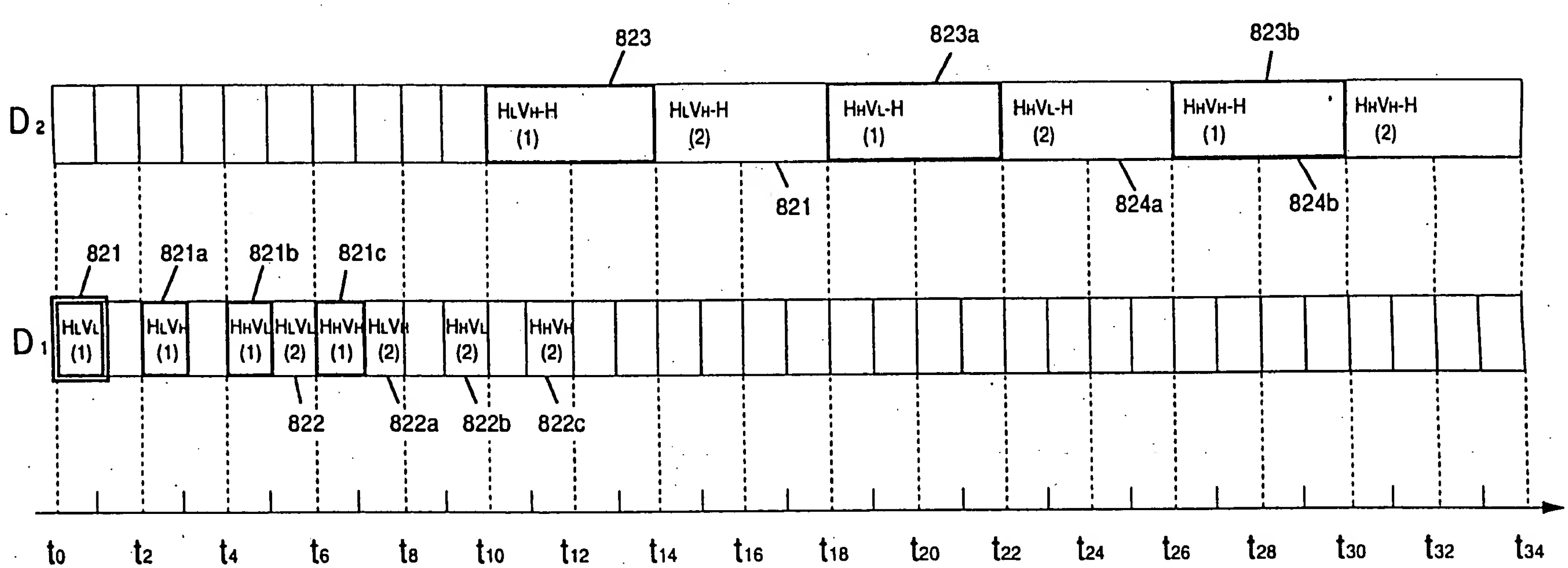
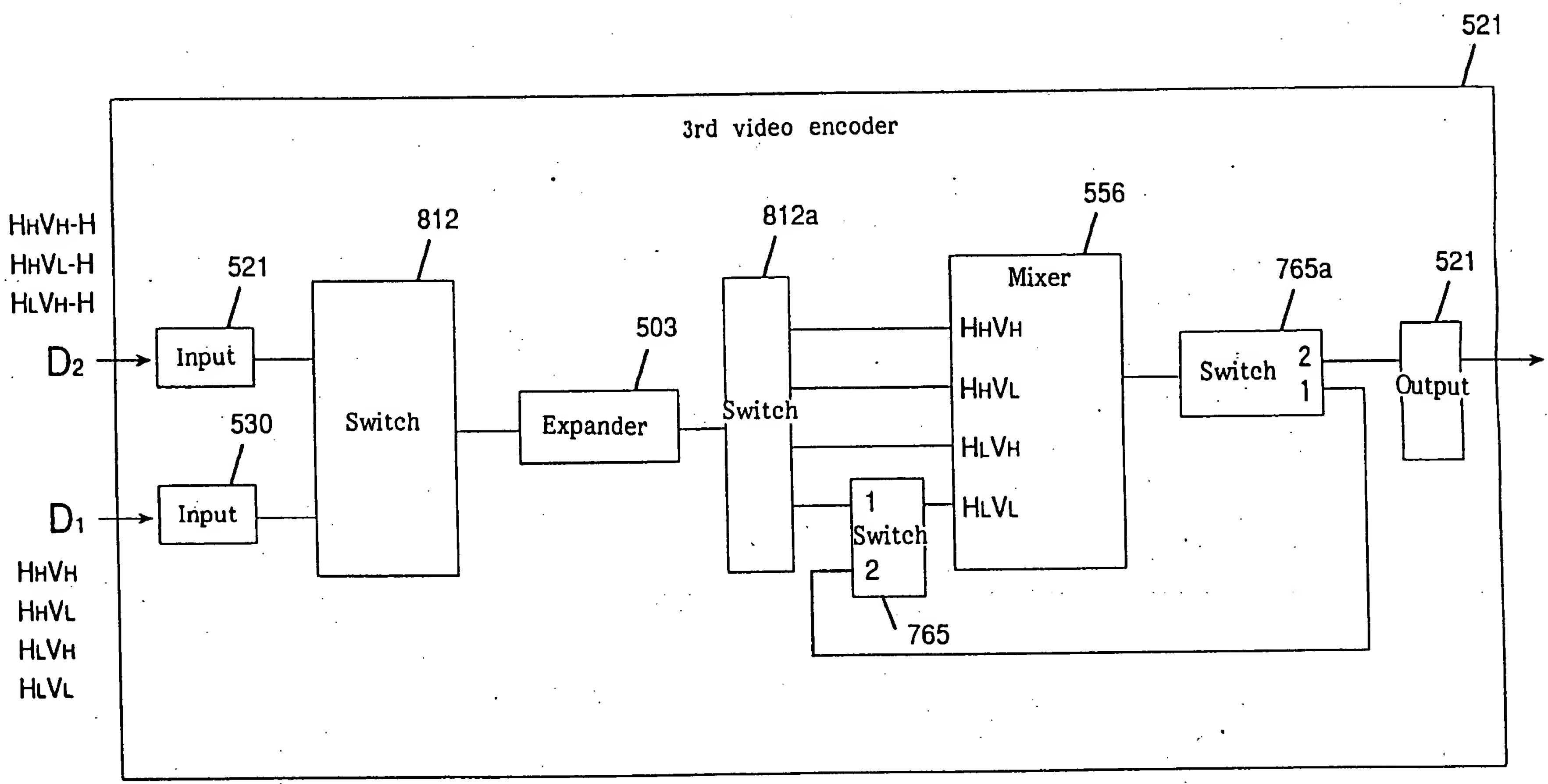
FIG. 77



07.12.92

FIG. 78



07.12.92

FIG. 79

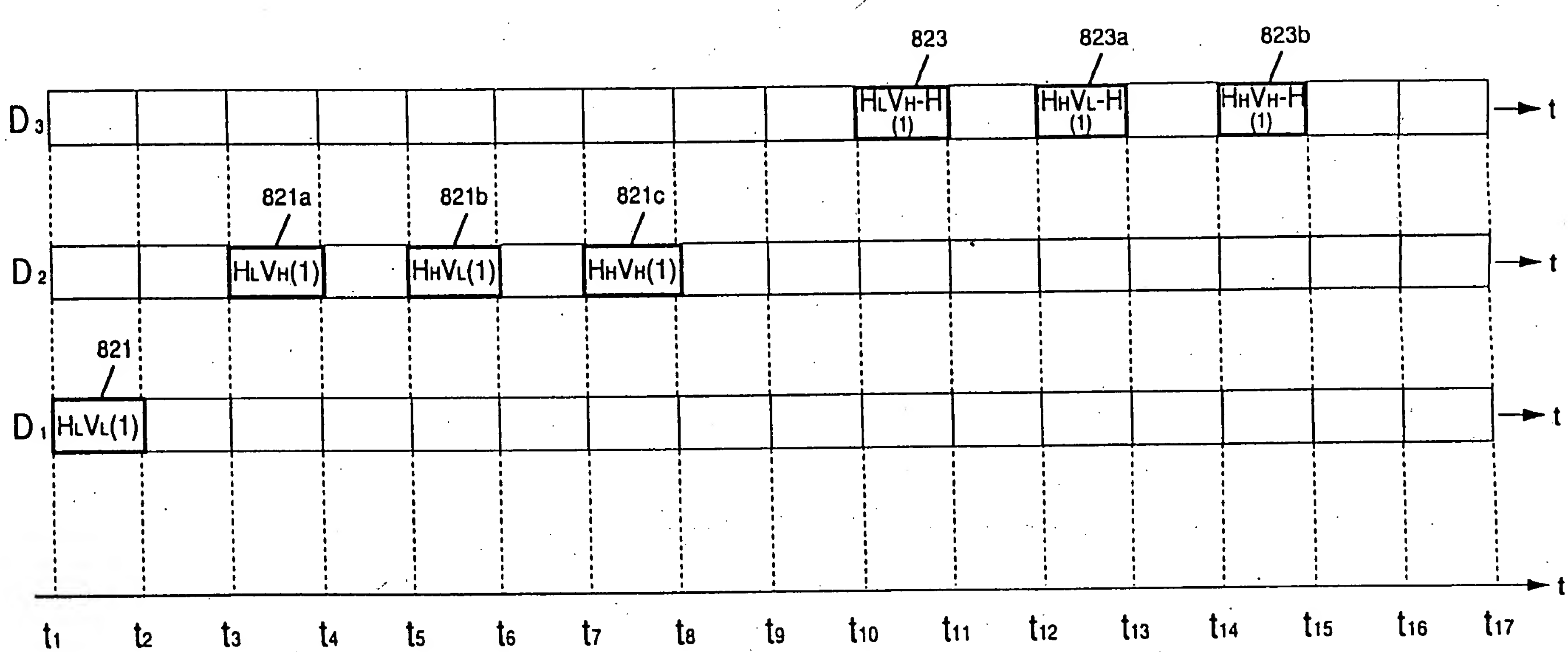


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FIG.80

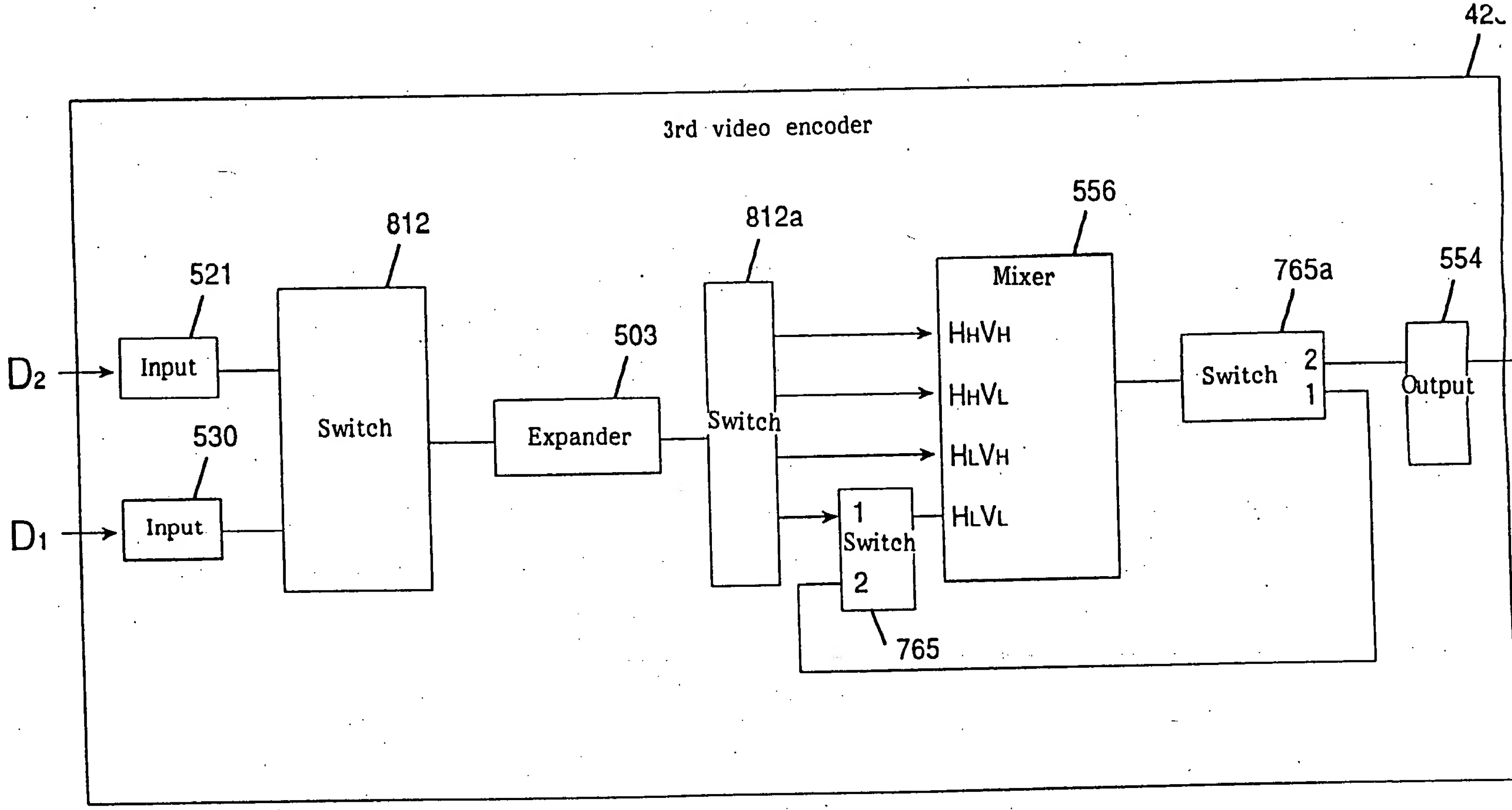

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FIG. 81

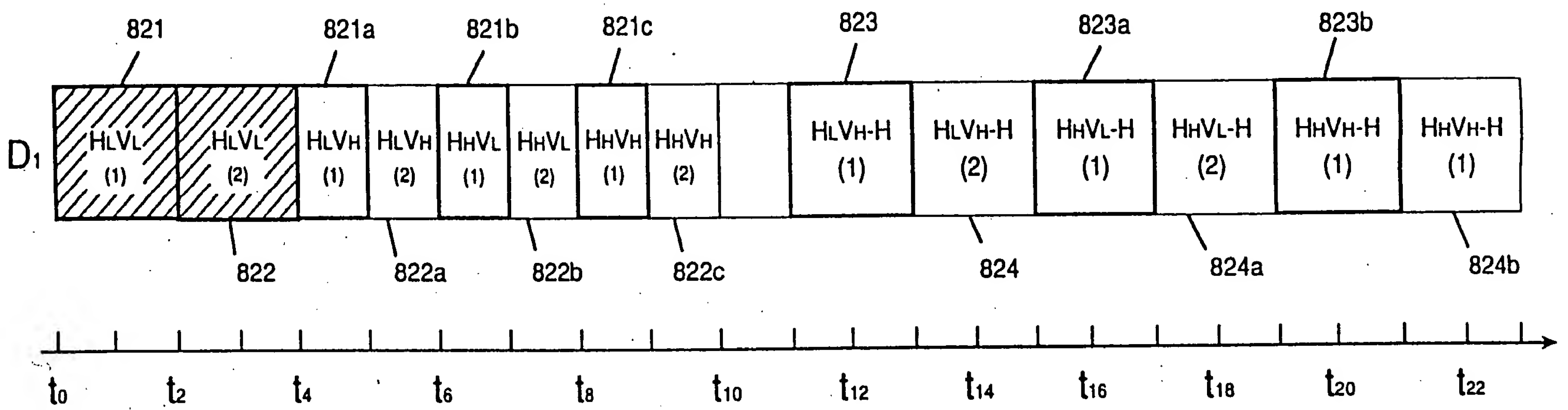

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FIG. 82

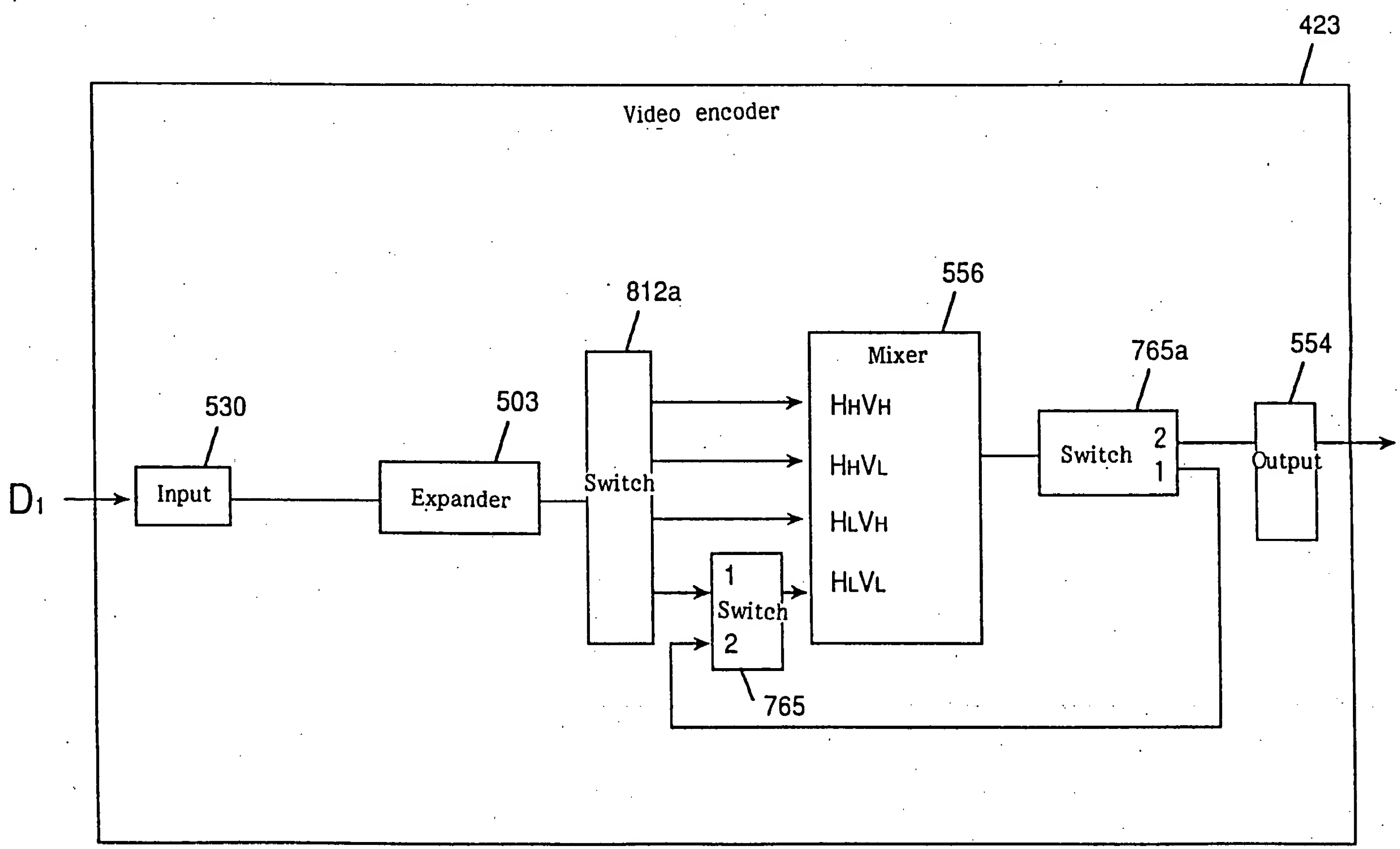
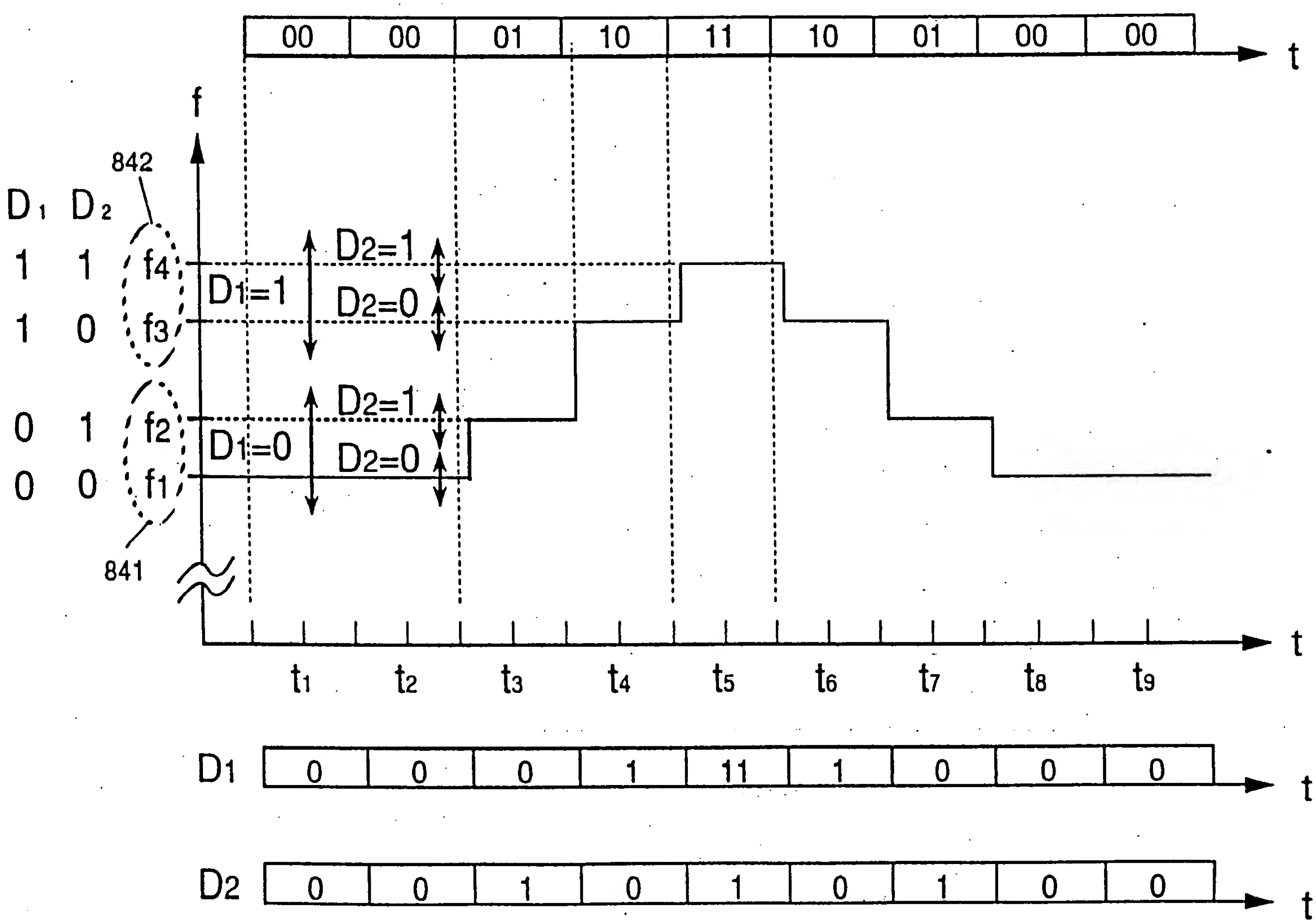
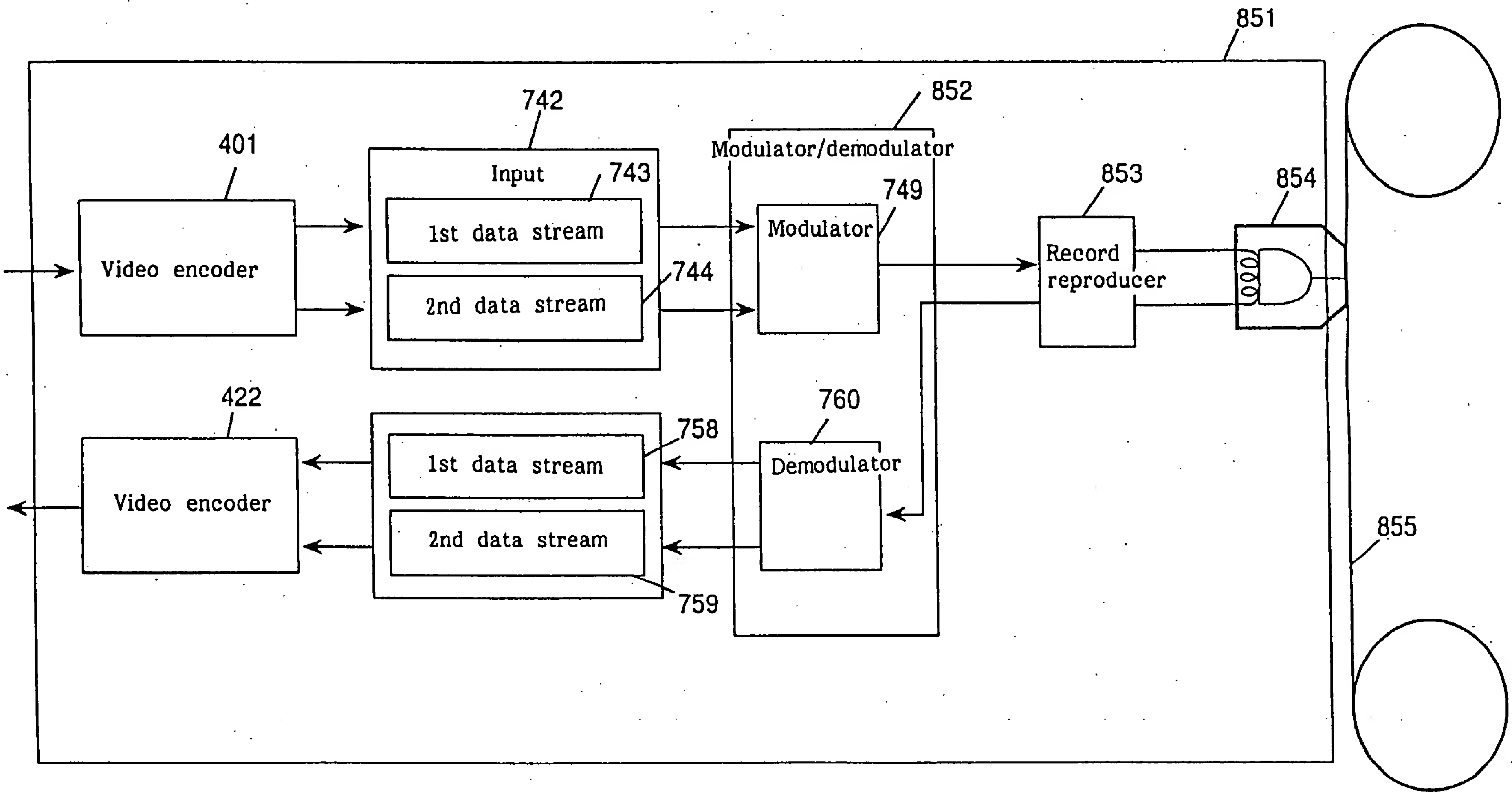

423
Video encoder
D_1
530
Input
503
Expander
812a
Switch
556
Mixer
H_HV_H
H_HV_L
H_LV_H
H_LV_L
765
1
Switch
2
765a
Switch
2
1
554
Output

FIG. 83



07.12.92

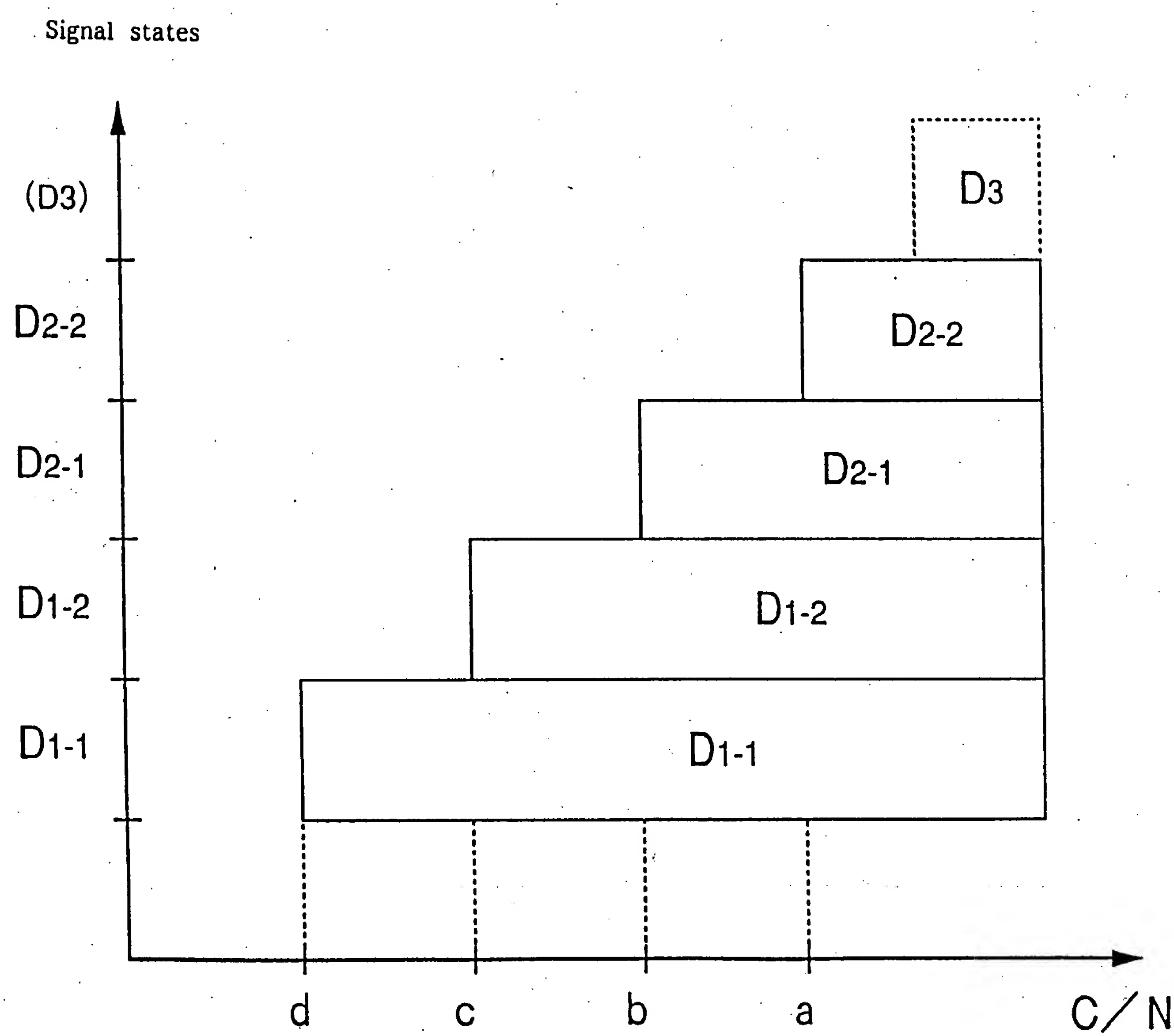
FIG. 84



851
852
Modulator/demodulator
742
401
Input
743
Video encoder
1st data stream
2nd data stream
744
Modulator
749
853
Record reproducer
854
422
760
758
1st data stream
Demodulator
Video encoder
2nd data stream
759
855

図85

FIG.85



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07.12.92

FIG. 86

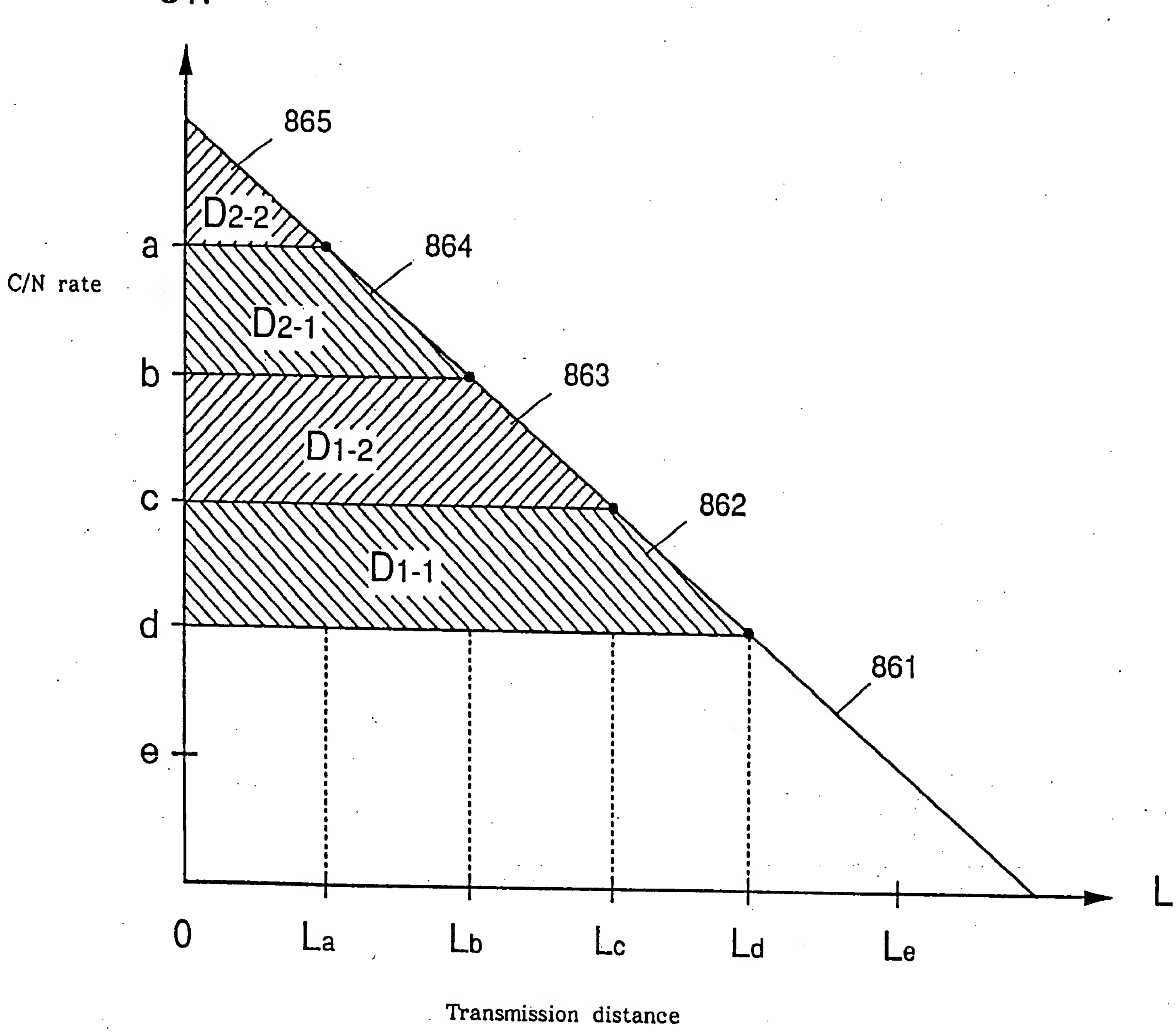
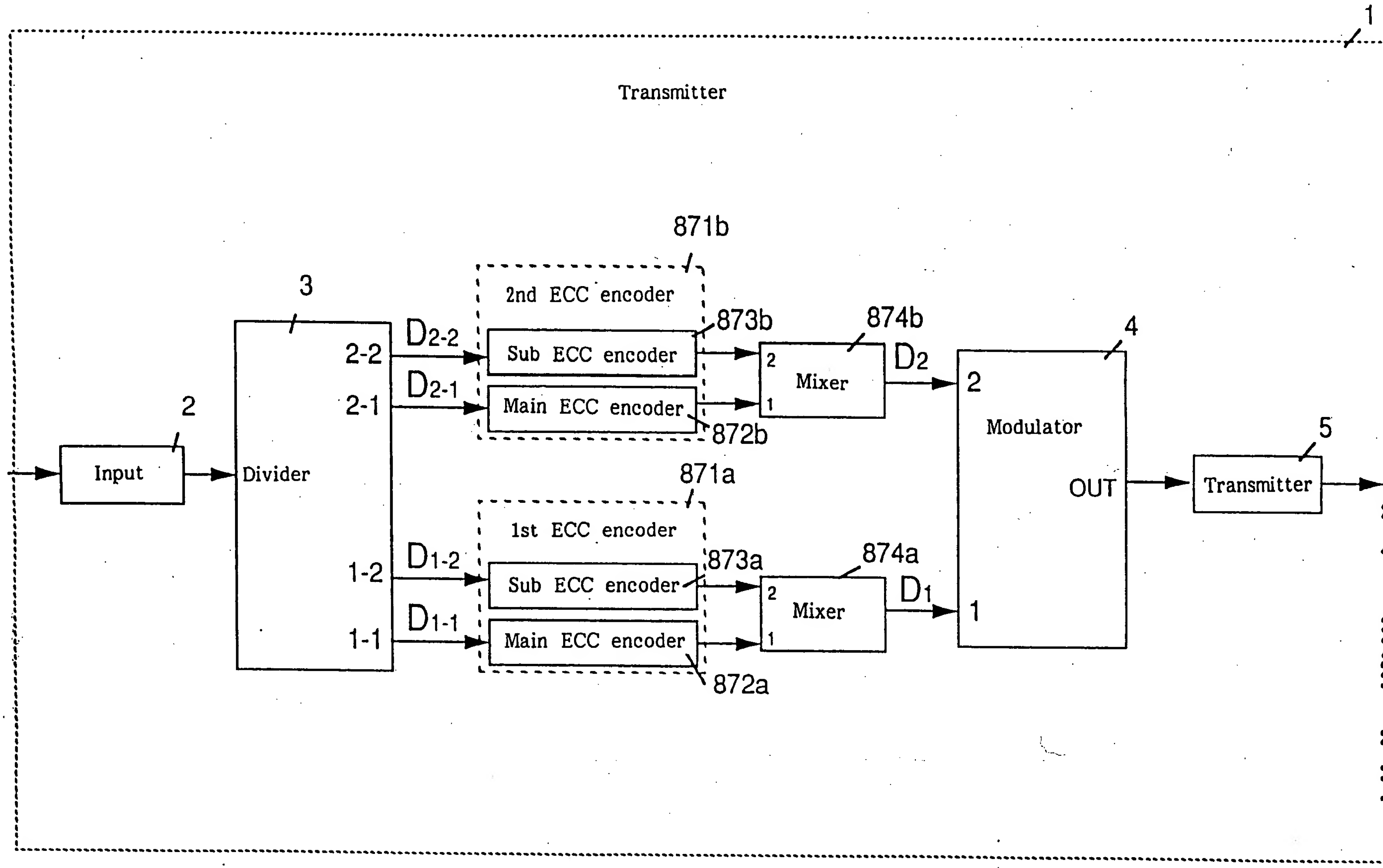


FIG.87



1
Transmitter
2
Input
3
Divider
2-2
2-1
1-2
1-1
D_{2-2}
D_{2-1}
D_{1-2}
D_{1-1}
871b
2nd ECC encoder
873b
Sub ECC encoder
Main ECC encoder
872b
871a
1st ECC encoder
873a
Sub ECC encoder
Main ECC encoder
872a
874b
Mixer
874a
Mixer
D_2
D_1
4
Modulator
2
1
OUT
5
Transmitter

FIG. 88

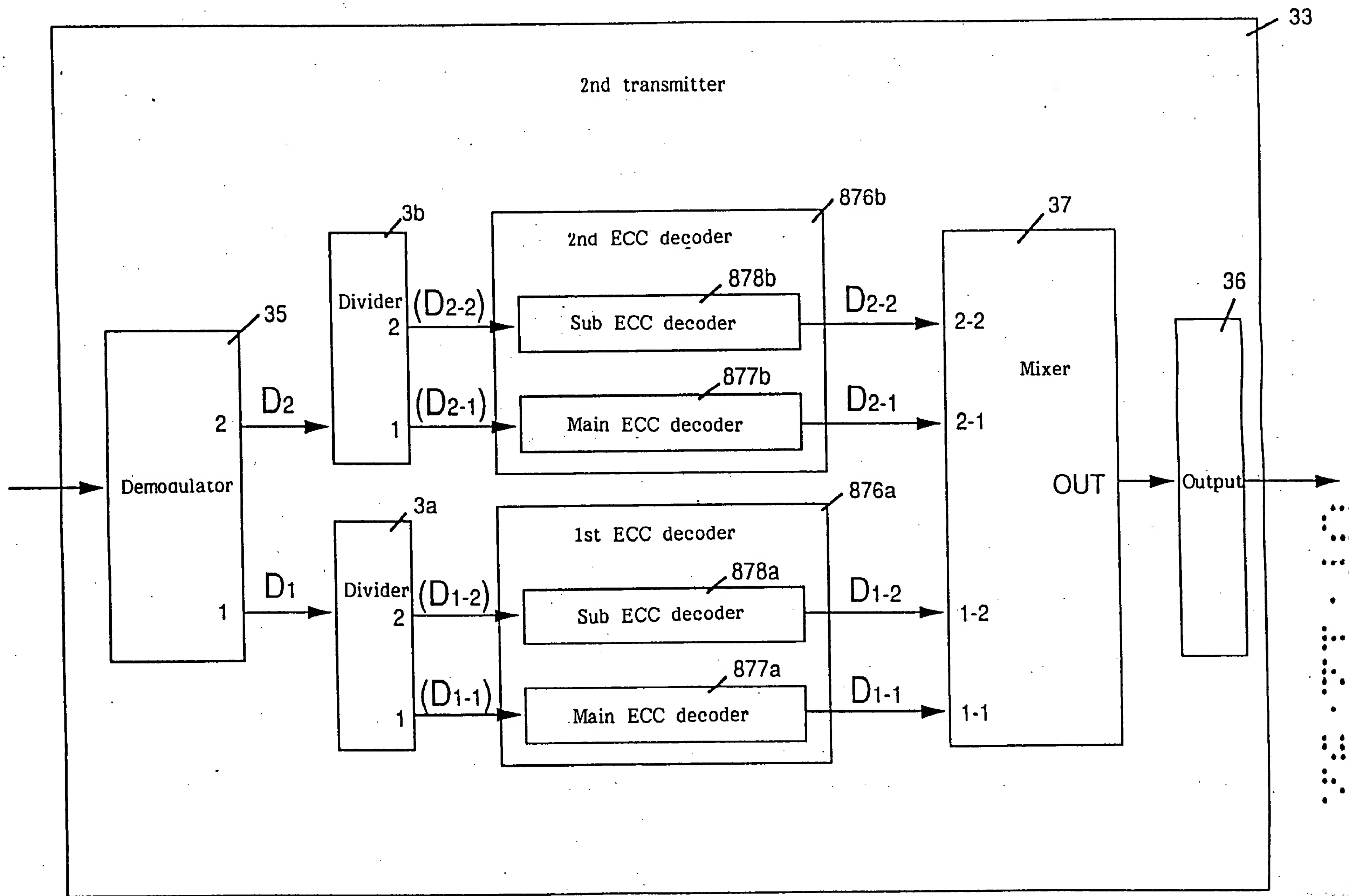


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FIG.89

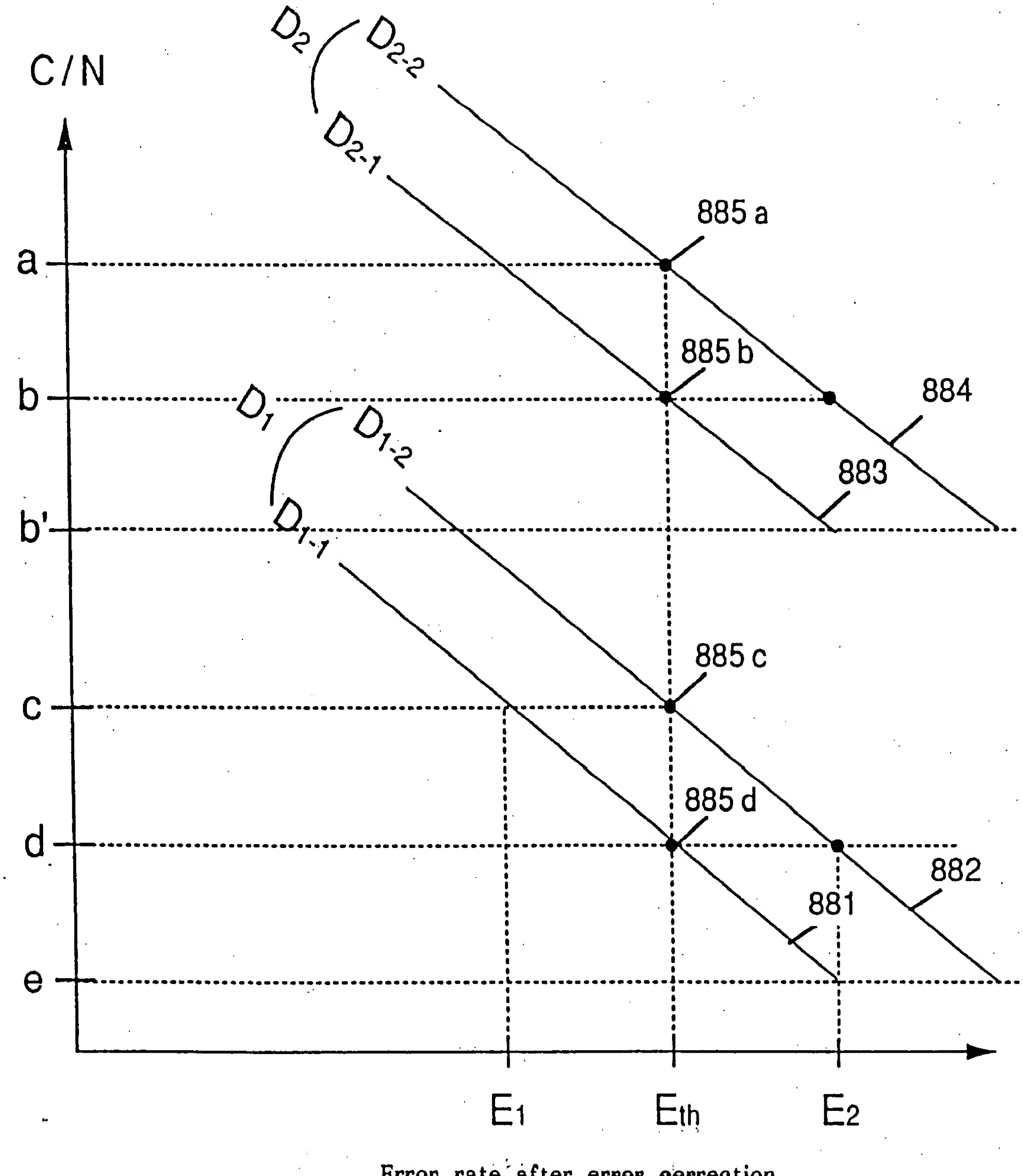

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FIG. 90

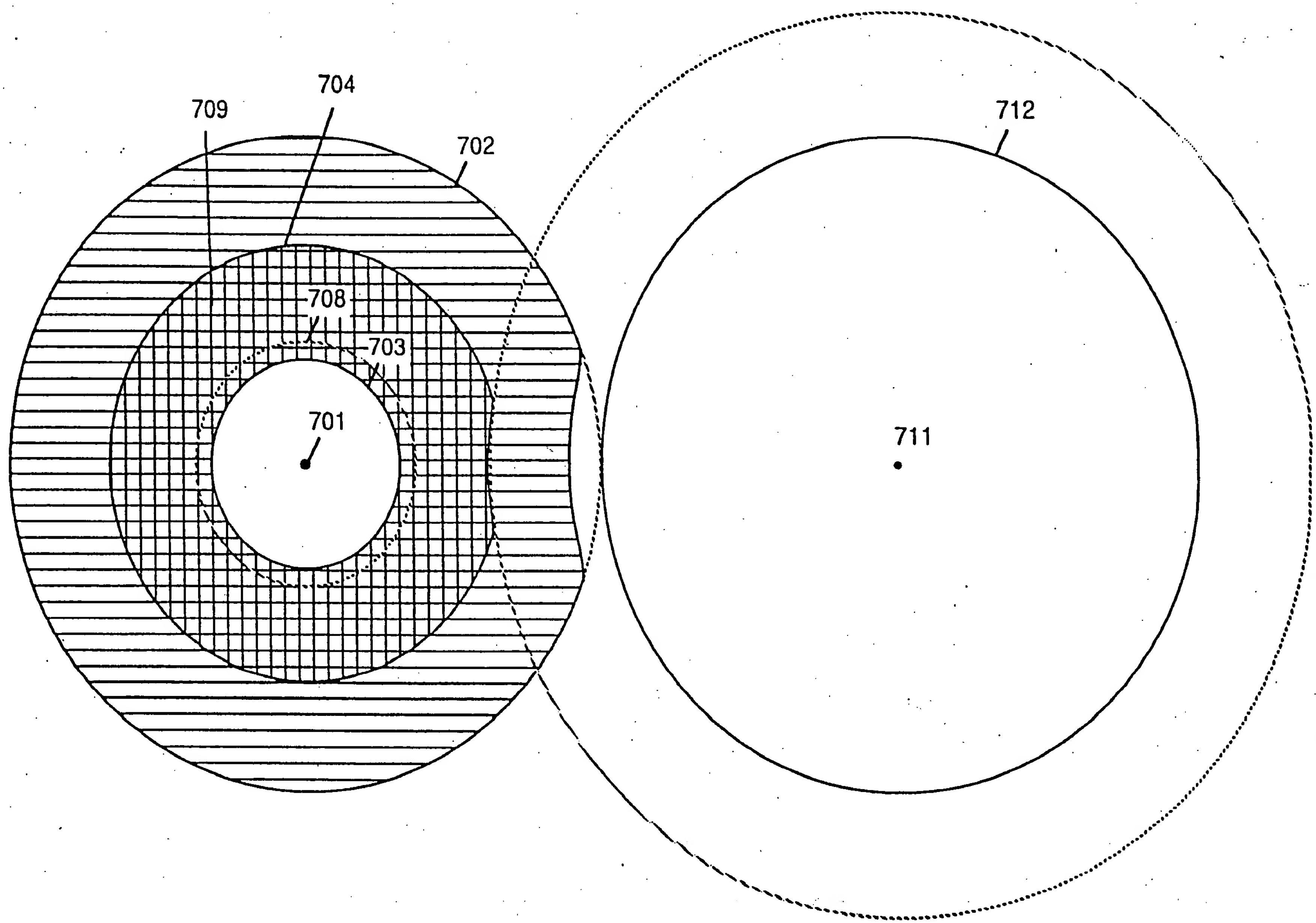

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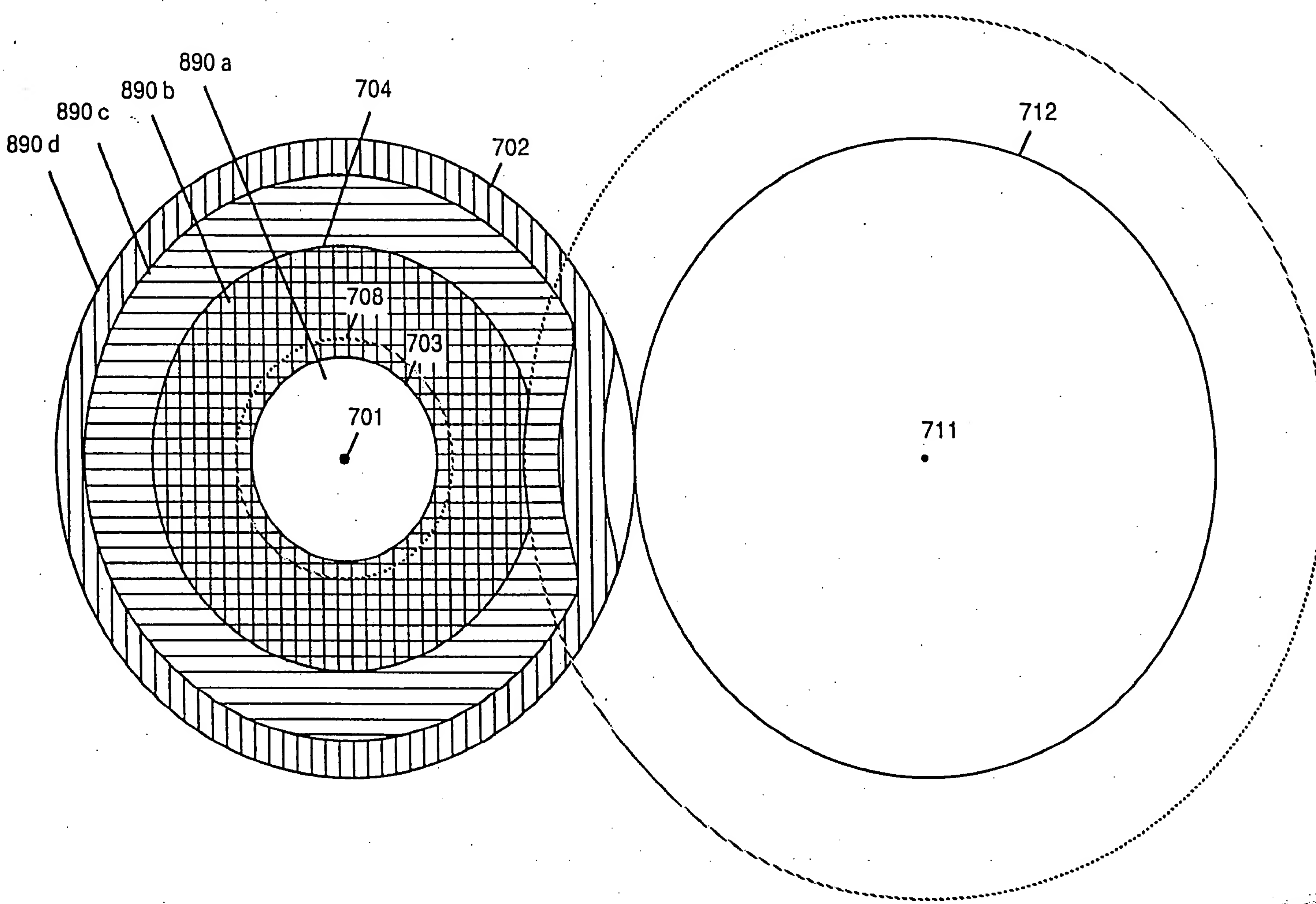
FIG. 91



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07.12.92

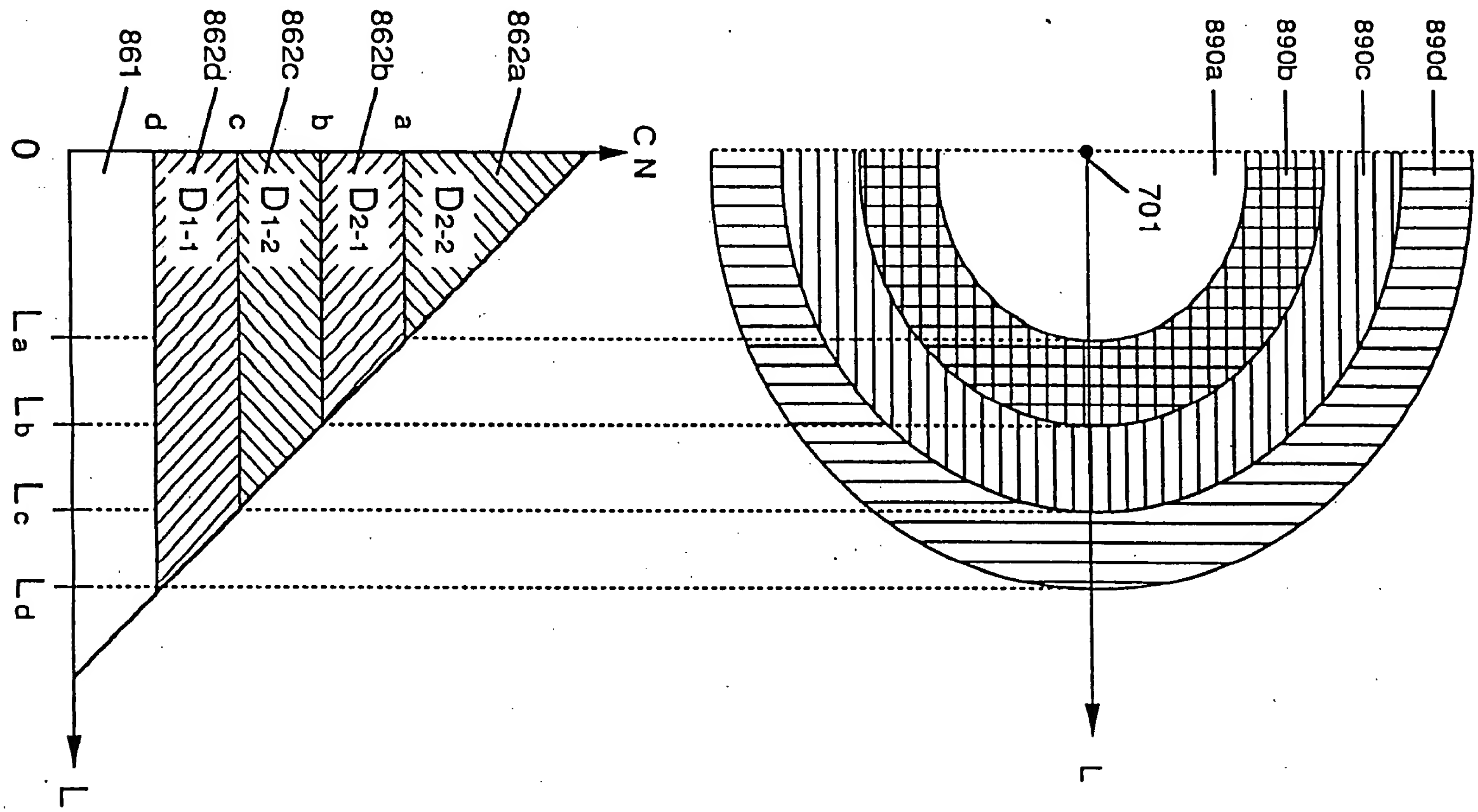

FIG. 92

FIG. 93

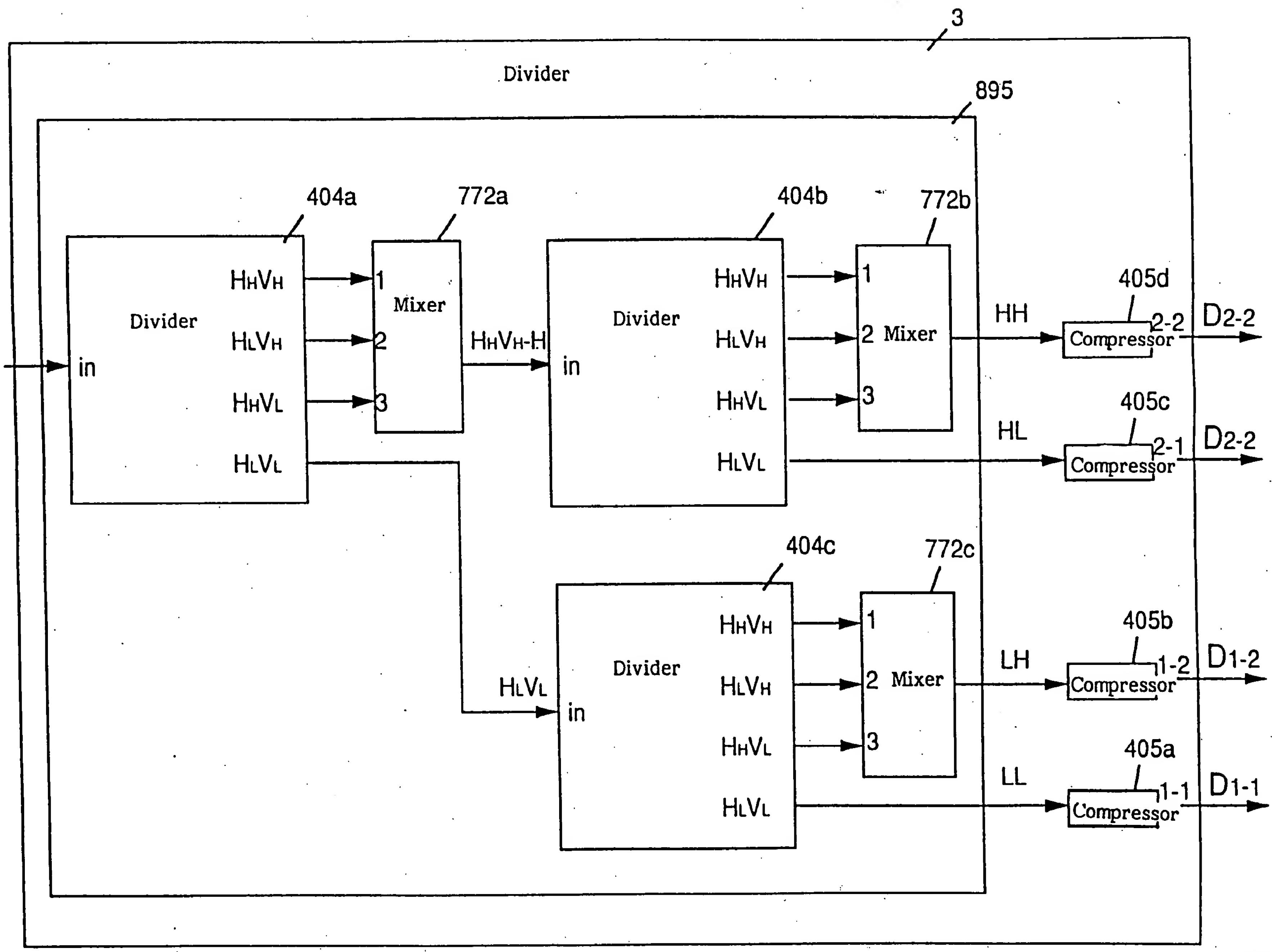

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FIG. 94

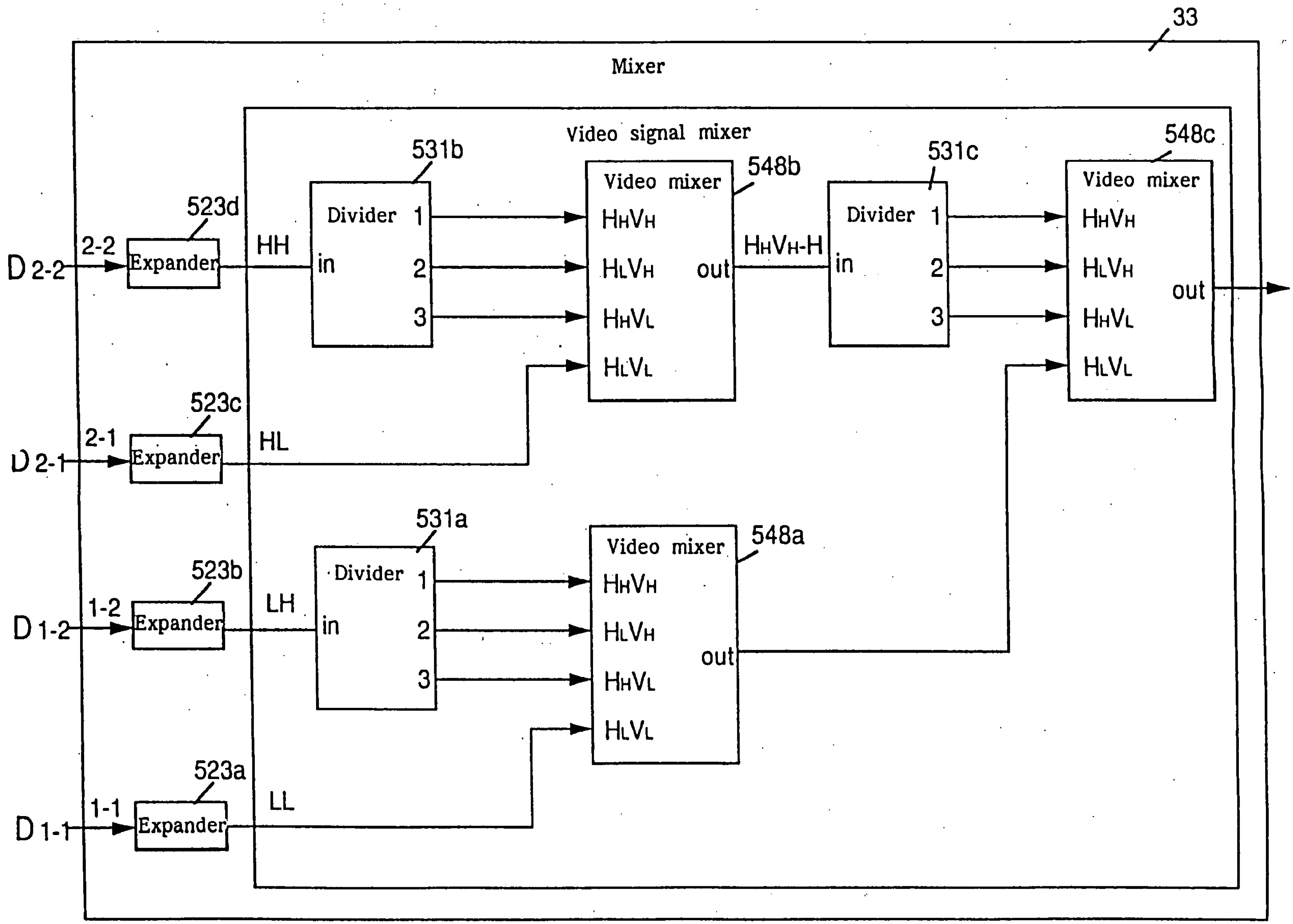

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FIG.95

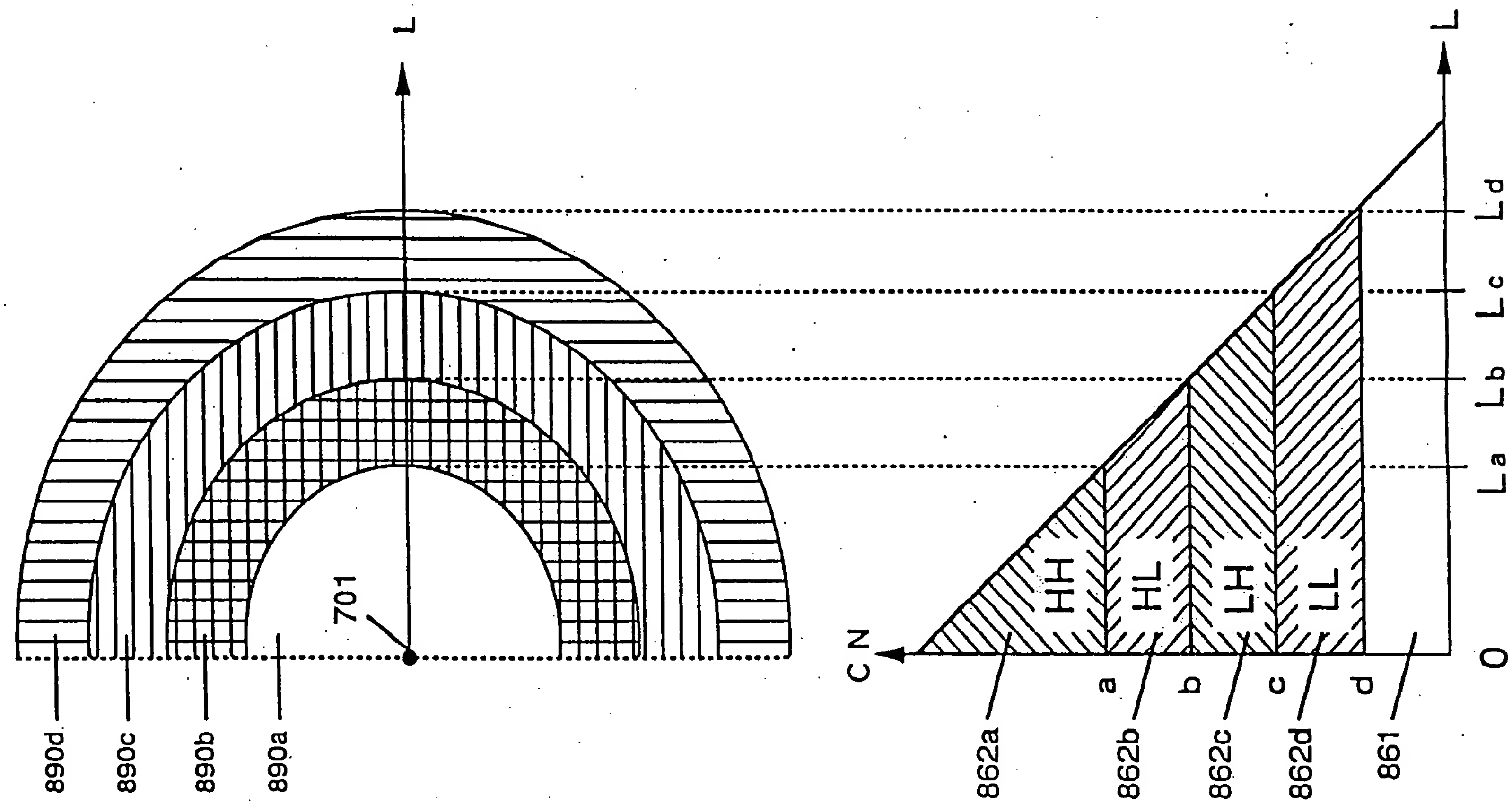

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FIG.96

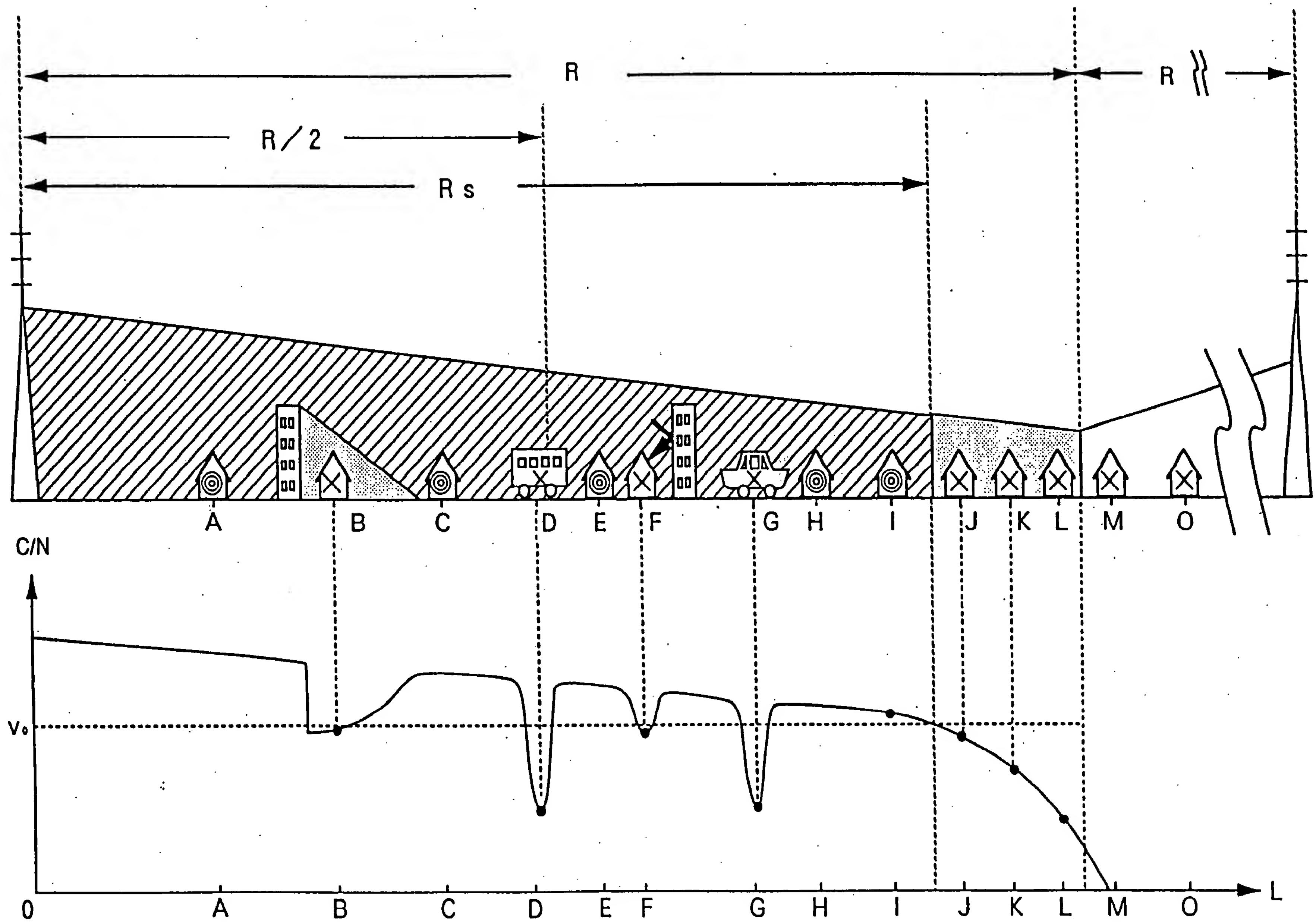

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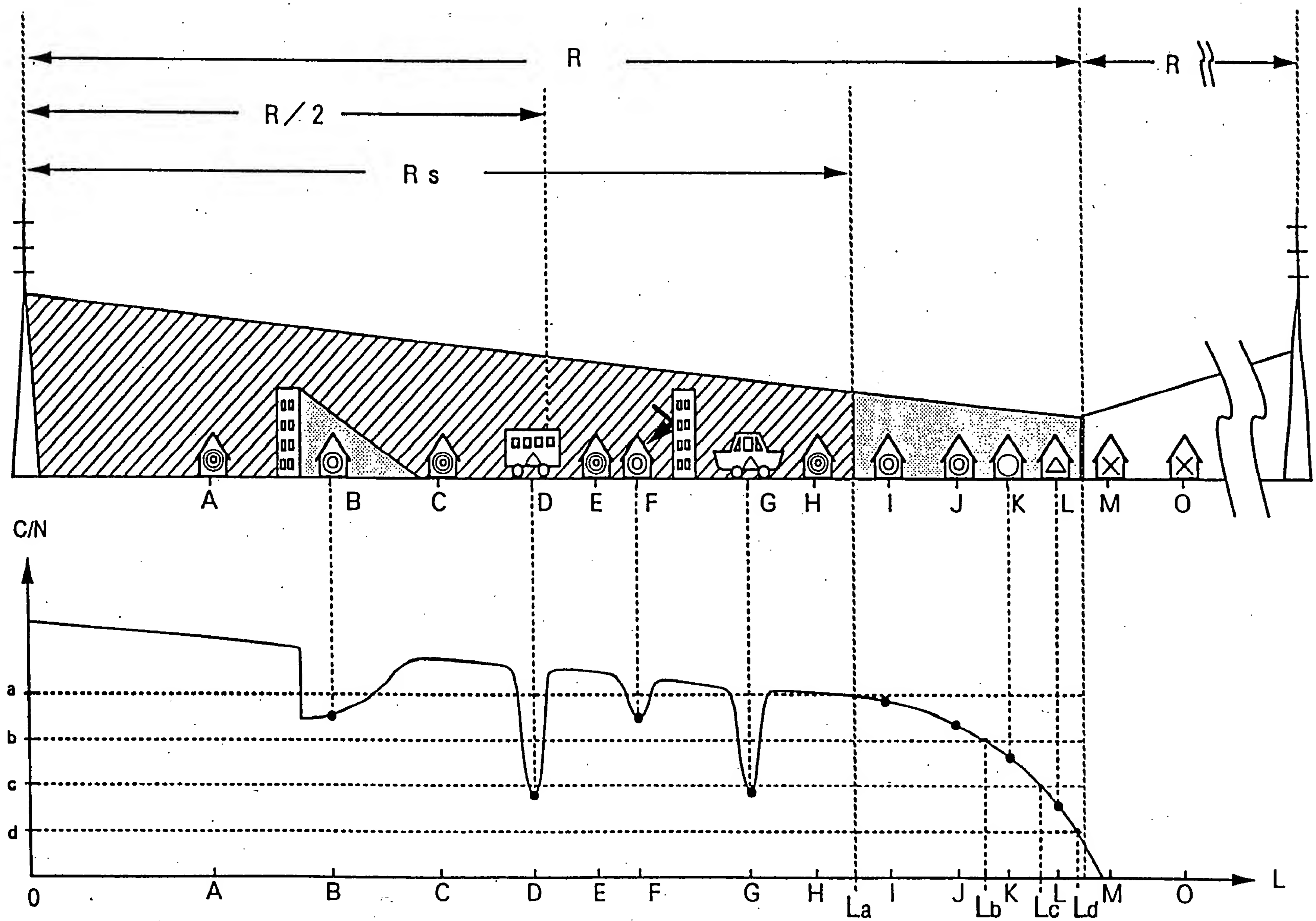
FIG.97



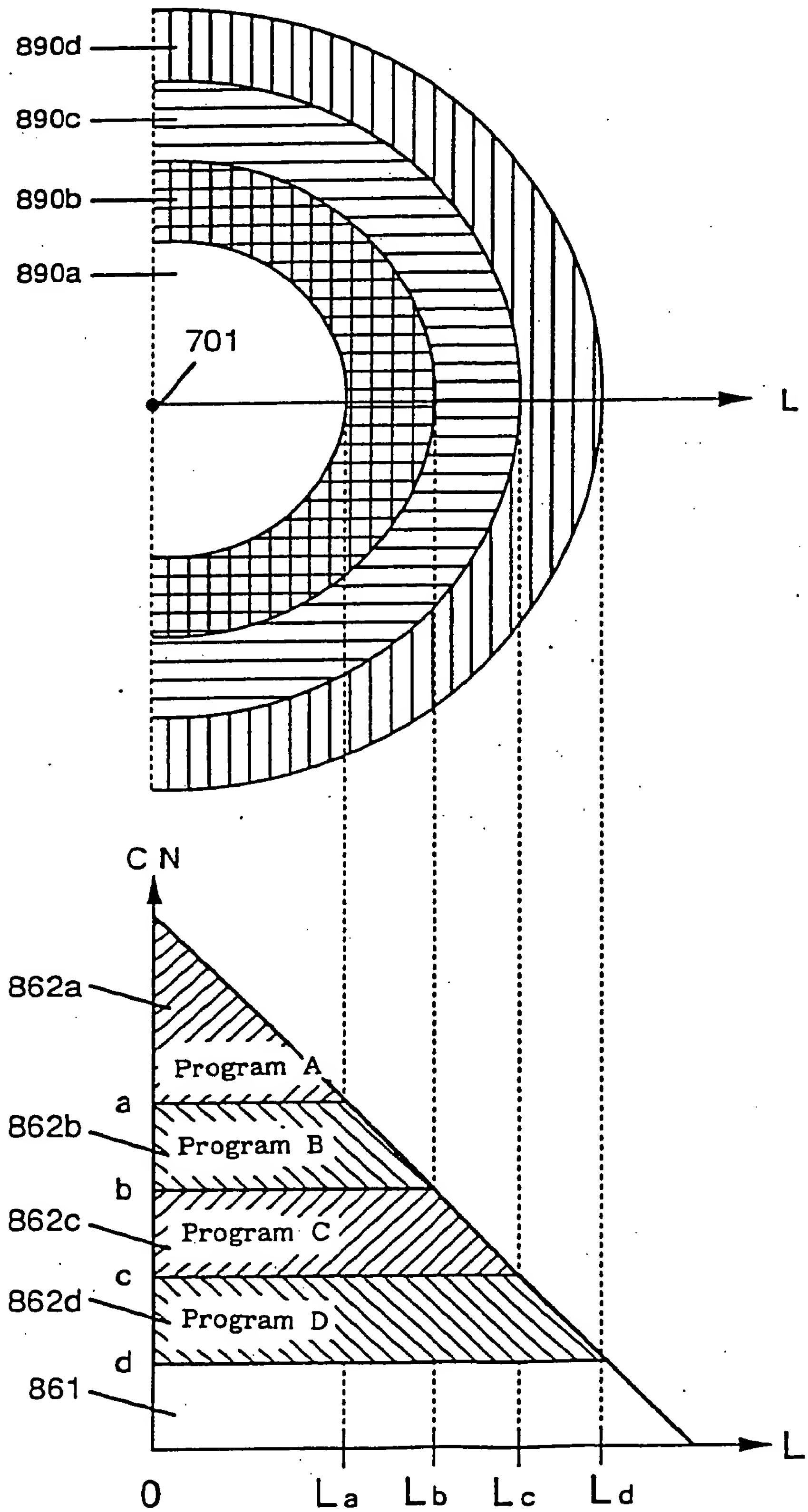


FIG.98

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Document name	Attorney appointment report
File No.	4030723003
Date presented	July 23, 1991
Addressed to	Secretary-General of Patent Office of Japan
Disclosure of the case	
Date filed	Patent petition presented on July 23, 1991
File No.	4030723003
Title of the Invention	Signal transmission system
Filing person	
Relation with the case	Patent applicant
ID number	000005821
Postal code	571
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Content reported	
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List of presented documents	
Inclusive letter of attorney number	9003129